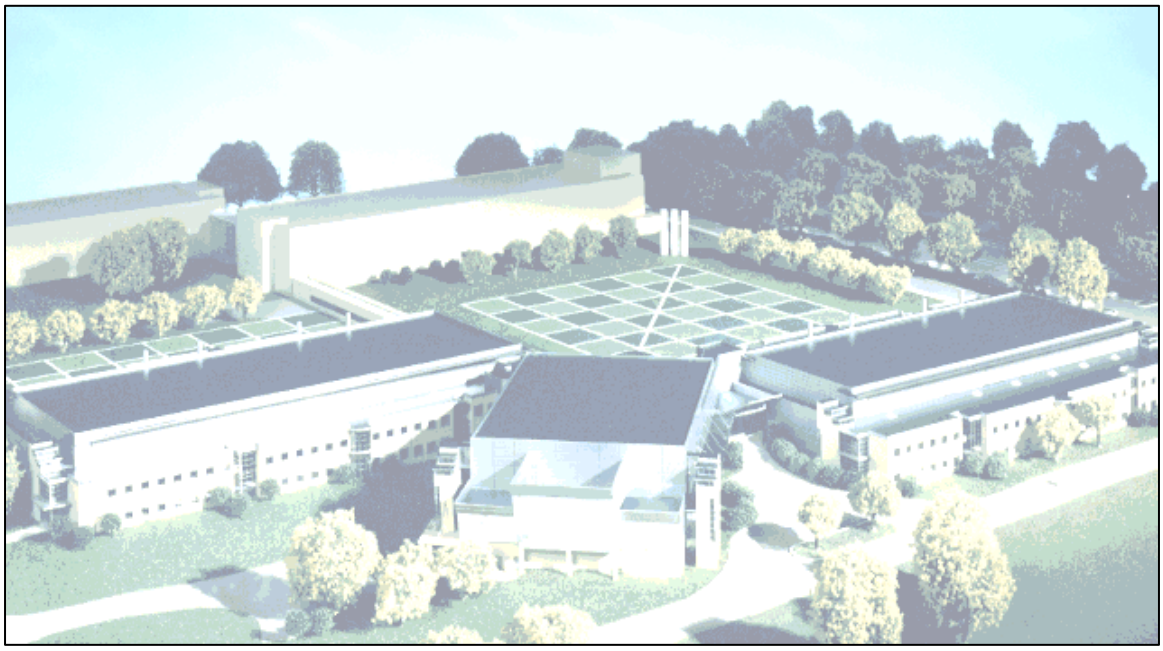
CNST NanoFab Cleanroom
Safety Manual



NIST CNST NanoFab Cleanroom
Building 215, Room D101
100 Bureau Drive
Gaithersburg, MD 20899

This manual was prepared for users and staff of the NIST CNST NanoFab Facility Cleanroom. Any comments or questions regarding the content of this manual should be directed to:
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Table of Contents

NIST CNST NanoFab Cleanroom Safety Policy

The Staff and Management of the CNST NanoFab Cleanroom have implemented all reasonable measures to ensure that the laboratory provides a clean and safe working environment.

It is the responsibility of all users and staff to act in a professional, courteous, and safe manner at all times while in the Cleanroom. Users violating the operating and safety rules of the Cleanroom or endangering the safety of themselves or others users, will be denied further access to the laboratory at the sole discretion of the management.

The CNST NanoFab Management

1. Introduction

This safety manual was developed by the NIST CNST NanoFab Safety Coordinator, and is specifically designed for the NIST CNST NanoFab Cleanroom. This manual is in compliance with all Federal Regulations and in accordance to OSHA Laboratory Standard, 29CFR 1910.1450, and NFPA 318, Protection of Semiconductor Fabrication Facilities. This document is a reference manual covering the basic operational policies for use of the NIST CNST NanoFab Cleanroom at NIST. It applies equally to all users and staff, and governs both safety and laboratory rules. All users are expected to have read and understood these procedures. This booklet, along with the mandatory safety training and written safety examination, is also expected to be sufficient training and notification for the Right-to-Know regulations for Laboratory Workers. Laboratory workers are expected to have a technical level sufficient to understand everything in this booklet.

The CNST NanoFab Facility Cleanroom is located at NIST in Building 215/Room D101. This Cleanroom is a shared access facility with over 80 certified users. The Cleanroom houses a multi-million dollar investment of semiconductor equipment that is fragile, and sensitive as to how it is used; the Cleanroom also houses toxic gases and chemicals, which pose significant hazards if handled incorrectly. This booklet attempts to document acceptable operating procedures and conduct for use of the Cleanroom. It is impossible, however, to define a policy for every conceivable situation. Rules and policies are no substitute for **common sense**. Under these conditions, anyone who fails to act in a professional, safe and responsible manner while in the Cleanroom (or any other part of the NanoFab) will be banned from further use of the facility at the discretion of the management.

Users' suggestions and feedback on the facility, its staff, its operation, and its equipment are welcome at all times. Please feel free to direct your suggestions to whomever you feel the most comfortable with.

2. General Lab Procedures

2.1 Access

Access to the Cleanroom is only granted to certified users and NanoFab staff who have completed the required NanoFab Cleanroom Start-up and Safety Orientation, and have completed the **yearly** required Safety Certification Examination with a passing grade. The user will be granted access that will allow personal access at any time during operating hours. Use of the Facility is a privilege that can be revoked by the NanoFab Management at any time.

2.2 New User Orientation

Cleanroom training has been developed by the CNST NanoFab Facility Safety Officer and must be attended by the prospective user, and is required before access to the Cleanroom is granted. The orientation is typically conducted in groups of 10 or less, but can also be conducted on a scheduled individual basis. The Cleanroom training is a two-part session. The first part includes a general presentation discussing how to use the Cleanroom and a Hazardous Products and Cleanroom Safety presentation, followed by a Cleanroom tour. The second part is a written safety examination. Part 1 takes approximately 3 hours. The exam can be taken anytime, but must be completed with a passing grade before an access badge can be obtained. Completing the examination is evidence that the user understood at least 95% of the information presented. This safety exam must be taken every year. If the exam is not completed with a passing grade or you do not take the exam, your existing access privileges will be deactivated until the exam is completed with a passing grade.

2.3 Locations (See Cleanroom Layout, section 10)

- **Main Entrance (Bldg 215/rm.D101):** This area can be accessed by users, staff, NIST Environmental Services, and authorized NIST Plant Personnel during normal operating conditions. The door is locked during outages, emergency procedures and under abnormal conditions. **Do not bring chemicals, waste chemicals, or cleaning products through the main entrance.**
- **Lockers Rooms:** The lockers and hangers are for regular users (at least one day per week). Non-frequent users, Visitors, and Students can occupy an empty locker on a daily basis, but will not receive an assigned locker unless it has been determined by the Management that a locker assignment is necessary. The locker is for your personal belongings, street clothes and shoes, coats, cell phones, valuables, wafer boxes, notes, etc. **Do not keep chemicals in lockers or in the gowning area**.
- **Gowning:** This area is a controlled environment and should only be accessed by certified users. Approved visitors can access this area when accompanied by a certified user, or a NanoFab staff member. Do not bring dirty or questionable items into this area. **Do not bring process chemicals through the gowning area. This includes fresh chemicals, chemical waste, and cleaning products. Use the approved chemical pass-through for transferring chemicals into the cleanroom.**
- **Cleanroom:** The Cleanroom areas can be accessed by a certified user, NanoFab staff, Environmental Services, authorized Plant Personnel, and visitors if authorized by the NanoFab Manager when accompanied by a certified user or NanoFab staff member. Frequent entry and exit is discouraged. The work conducted in the cleanroom is performed with toxic gases, hazardous chemicals, and potentially dangerous equipment. Always be aware of those who are working around you. Move carefully throughout the cleanroom so you do not disturb, or interfere with work being conducted. Chemicals are periodically refreshed and are introduced into the cleanroom by the user or NanoFab staff. The chemicals for the cleanroom are retrieved from the chemical storage areas (room D106) and properly transferred (see section 5.1 Chemical Handling) to the service chase(s) adjacent to the cleanroom bay and placed into the appropriate chemical pass-through (acid or solvent).

- **Service areas:** These areas are identified by signs displaying **"Restricted area NanoFab Staff Only"**. Users are not allowed to enter these areas unless specifically authorized by a member of the Cleanroom staff. Staff and users are discouraged from entering the service areas from the cleanroom unless absolutely necessary. Proper entry to the service areas is from the Class 1000 hallway (use pre-gowning protocols). The service areas are hard to see from the cleanroom and if a person is injured, it may be difficult for them to receive help. NanoFab Staff members can access this area when needed. The areas under the raised floor can be accessed by NanoFab staff, and NIST Physical plant only. The service areas in the sub-fab can only be accessed by NanoFab staff, and NIST plant personnel. The Liquid Nitrogen Area outside bldg. 215 can be accessed by NanoFab staff, Vendor Delivery Personnel, and Plant personal only.

2.4 Cleanroom Conduct

This Government Research Laboratory is a Class 100 Cleanroom, where proper conduct and a professional attitude are required at all times. This facility is used NIST wide and many sensitive experiments with many hours of work are taking place on a regular basis. You must act in a manner that will not disrupt, or disturb other researchers using the Cleanroom. As a user of the Cleanroom you are responsible for reporting any activities that deviate from normal behavior. The violator(s) may lose Cleanroom privileges based on the discretion of the CNST Management.

2.5 Hours of Operation

The normal hours of operation are 7:00 am to 7:00 pm. Usage outside of the operating hours must be authorized by the CNST NanoFab Manager. Authorized users utilizing the Cleanroom outside of the operating hours must have authorization and comply with any and all responsibilities dictated by the NanoFab Management.

2.6 Security Cameras

Security cameras are located throughout the Cleanroom, and in other areas of the facility. This allows 24/7 remote monitoring of the Cleanroom. The Camera system has a digital storage capability for 2 months of video recording. The NanoFab staff and the NIST Emergency Services Division will have the capability to monitor the activities within the Cleanroom from a remote location at any time.

2.7 User Communication

All users must supply the CNST NanoFab Management with a working email address that they can check on a daily basis for messages relating to the NanoFab. The CNST NanoFab Forum is a secondary communication mechanism to notify the users of outages, High-level tours, equipment status, etc. Questions, comments, or suggestions about any safety issue, this manual, or other concern can be directed to any member of the NanoFab staff, at any time.

2.8 NanoFab Governance and Appeals

The management of the NanoFab is responsible for the continued operation and existence of the NanoFab. Use of the NanoFab by any user is at the sole discretion of the management. The NanoFab management and staff are responsible for maintaining and enhancing the equipment resource of the NanoFab, and for assuring that the operational policies of the NanoFab are followed. On matters involving equipment usage or safety, you must follow the direct instructions of the NanoFab staff. Both staff and user are expected to act in a courteous and professional manner at all times. Deviations from this norm by either users or staff should be reported to the NanoFab Management immediately.

If at ant time you, as a user, feel that you have been unfairly treated by a staff member or strongly disagree with the rules imposed by a staff member, please discuss the situation with the NanoFab Manager.

2.9 NanoFab Safety Committee

The NanoFab Safety Committee is organized to promote increased safety in NanoFab operations. They review safety policies, procedures, and recommend changes to implement best practice operations. The group consists of NIST employees with various backgrounds. Their names and contact information can be found below.

NanoFab Safety Committee

Name	Title	Department	email	Office Phone
Russ Hajdaj	NanoFab Safety Coordinator	Center for Nanoscale Science and Technology (CNST)	rhajdaj@nist.gov	301-975-2699
James “Mike” Blackmon	NIST Safety	NIST Safety, Health and Environment Division/ Environmental Compliance Group	mike.blackmon@nist.gov	301-975-5822
Dennis Myers	NIST Safety	NIST Safety, Health and Environment Division/ Safety Office	dennis.myers@nist.gov	301-975-5823

3. Equipment use

3.1 Approved Users

Access to the NanoFab itself does not permit use of any particular instrument. The equipment in the may be used only by certified users who have also been specifically trained in its use and approved **by a member of the NanoFab Staff**. The equipment in the NanoFab is highly sophisticated and delicate, and can be potentially hazardous if not used properly. Each instrument has operating instructions, restrictions, and safety rules in place to ensure the continued operation of the instrument and this is strictly enforced by the NanoFab Staff and Management. Failure to follow the operating procedures or rules can result in injury, expensive equipment damage, and unaffordable downtime. Consequently, careless or damaging use of the equipment will result in suspension of users' privileges, either for a specific instrument or the NanoFab as a whole.

3.2 Equipment Operations

Operating procedures are presented to the user during equipment training and should be maintained by the user for future reference. Operating procedures and instructions manuals are available online at the following website.

http://nanofab.cnst.nist.gov

3.3 Equipment Problems

For the safety of the user, please report all equipment damage or malfunctions to the Cleanroom Staff. **DO NOT TRY TO REPAIR THE PROBLEM YOURSELF**, this could result in injury, expensive damage, and extended downtime.

4. Laboratory Practices

4.1 Visitors

Visitors into the Cleanroom must be authorized by the NanoFab management and escorted by a staff member or certified user. Visitors are not allowed, for any reason, to operate equipment, use chemicals, or to be left alone. An authorized service contractor may be left alone, but must first be authorized by the NanoFab Manager and trained by the NanoFab Safety Officer or NanoFab Staff, and must be provided access to a contact person at all times.

4.2 User Storage

Do not store chemicals in user storage lockers. All chemicals are to be stored in an approved area and the container must be labeled properly.

4.3 Phones

There are phones throughout the Cleanroom. Inside the cleanroom there are 12 phones located near the main center hallway at the ends of the work bays. The cleanroom phones are large, easy to see, hands free operation. The phones can be used for person-to-person communication, paging, and for emergencies. There are wall mounted phones located around the perimeter of the cleanroom in the visitor corridor. All phones dial outside lines: Dial 9 then the number. For emergencies at NIST call **x2222**.

Emergency calls: When an injury occurs in the Cleanroom, dial **2222** and provide the room number (located above Cleanroom phones) and the type of injury to the emergency responder.

4.4 After-Hours Policy

The Center for Nanoscale Science and Technology's NanoFab Facility, i.e., cleanroom/215, C02-2/215, and E102/216, is open Monday thru Friday from 7 am to 7 pm. Technical staff members are available during these hours to assist active users and to respond to any safety issues that may arise.

In general, users need to schedule and conduct their work during normal operating hours in order to adhere to the NIST Laboratory Safety Policy.

Under special circumstances, the CNST NanoFab Facility Manager may allow a user to access the NanoFab during off hours on weekdays or on the weekends. Off hours access will be authorized by the CNST NanoFab Manager on a case-by-case basis for specific dates and times only. Users who have been approved for off hour's access will be issued a temporary badge that will allow lab access only during the agreed upon time. Limited availability of a tool or convenience are NOT valid reasons to request off hour's access. If the availability of a tool is an issue, a solution is to plan your research further in advance using the Coral software system.

Off hour's access is limited to Monday through Friday from 7 PM to 10:30 PM, and Saturday and Sunday from 7AM to 10:30 PM. Users may not enter the lab before 7 AM and must vacate the lab by 10:30 PM.

Failure to comply with these policies for NanoFab use may result in the suspension of your Coral account and the revocation of NanoFab access privileges.

Lab users needing extended access should complete the Off Hour's Access form (see attachment) and forward it to the facility manager no later than 5 business days before the proposed start date of off-hours access.

Off-hour's access to the CNST NanoFab is granted under the following circumstances:

1. **Authorization**
   Users must receive prior authorization EACH time off hours lab access is needed. Authorization is approved by the CNST NanoFab Facility Manager only. Users requesting access must submit a request form no later than 5 days before off hours NanoFab access is necessary.
2. **Access**
   Users who have received authorization from the facility manager will be issued a temporary visitor badge to allow access for the agreed upon dates and times.
3. **Buddy system**
   Any user wishing to access the lab off hours must be accompanied by another researcher who is also a facility user. Both users must be signed in.
4. **Notification**
   All users must notify the NIST emergency services division line at extension 6190 at each of the following times:

   - When entering and leaving a lab on a weekend
   - When entering a lab after 7 PM on a weekday
   - Promptly at 7PM on a weekday if remaining in a NanoFab Facility
   - Upon leaving the NanoFab for the night. All users must vacate the lab by 10:30 PM.

4.5 Cleanroom Shutdown

Cleanroom shut downs are regularly scheduled events and also occur in the event of a storm, building faults, emergency, etc. A NanoFab staff member is responsible for containing the process gases, and properly shutting down the power to predetermined areas of the Cleanroom to eliminate the chance of fire or equipment damage. During the time of the shut down, the Cleanroom will be locked and no access will be granted for any reason.

4.6 Safety Glasses/Contact Lenses

Safety Glasses are required at all time when working in the Cleanroom. There are safety glasses available to all users in the locker room. You can keep them in your storage space, but they must be returned when you no longer intend to use the lab. Visitors are required to wear safety glasses. Contact lens use in laboratories has been disputed for years. The American Chemical Society has approved the use of Contact lenses for laboratory workers, and they are permitted in the NanoFab Cleanroom, but are not a substitute for safety glasses. A second pair of contact lenses or prescription glasses is recommended as a backup.

4.7 Cleanroom Alarms/ Evacuation

There are numerous alarms in the Cleanroom. The user must be able to identify the alarm quickly, and act accordingly. If you cannot identify the alarm leave the lab immediately through the nearest exit and notify NanoFab staff.

Types of Alarms:

- **End of Cycle Alarm:** Some alarms signify end of cycle on some instruments; these are usually not very loud, and may be recognized by a repetitious beep.
- **Exhaust Failure Alarm:** Only activated in the main control room. The individual NanoFab tools themselves will alarm when the tool senses loss of exhaust. Contact a NanoFab Staff Member.
- **Fire Alarms:** These are located throughout the Cleanroom. They can be recognized by a flashing strobe and horn. Some of these devices provide verbal instructions, but you are required to leave the lab immediately and *do not stop to remove your gown*.

Assemble outside in the small parking lot on South Street in front of the building, so you can be accounted for. *You are also required to leave the lab in the event that the fire alarm was sounded for a practice drill.*

- **Toxic Gas Detector Alarms:** These are identified by a loud repeating beep with the activation of the yellow flashing evacuation strobe. You are required to leave the lab immediately.
- **Power Disruption/Power Loss, HVAC Failure, Chemical Exhaust Failure:** Only activated in the main control room. The individual tools themselves will alarm when the tool senses loss of exhaust. Contact a NanoFab Staff Member.

Emergency Evacuation Procedure:

1) Do not stop to remove your gown.
2) Contain any hazardous work in progress if possible.
3) Leave the lab through the nearest exit.
4) Avoid heading towards the Oxidation/Diffusion Furnace room (B106).
   This area has many of the hazardous gases being used.
5) Assemble outside in the small parking lot on South Street in front of the building, so you can be accounted for.

4.8 Injured Person Retrieval

A person injured in the lab may require immediate attention. **Safety is the number one priority of this Cleanroom.** It may be required that safety personnel enter the cleanroom without following the cleanroom protocols. They are trained to retrieve or treat the person on the spot if it is required to do so.

5. Chemical Safety

5.1 Handling/Labeling

Handling chemicals in the cleanroom is a common practice. Chemicals are retrieved from the chemical storage area (room D106) and are introduced into the cleanroom via an airlock or pass-through.

- **Transport:** Use bottle carriers when transporting bottles, *especially* glass bottles. Use the chemical cart if transporting multiple bottles. Do not transport chemicals that are incompatible with one another. Never transport acids with solvents or bases. Acids produce heat from an exothermic reaction and can ignite solvents. Acids that mix with strong bases produce violent reactions that can cause the chemicals to suddenly splash onto the user.
- **Chemical Deliveries:** Chemicals are delivered to the bldg 215 loading dock, and will require transport to room D108. The NanoFab Staff Member will retrieve the chemicals, wipe them down, and place them into the appropriate chemical closets. All bottled chemicals must be handled with chemicals resistant gloves and eye protection. It is a recommended practice to wash hands after handling chemicals and chemical containers.
- **Pouring:** Move slowly, and hold the bottle with two hands. One hand should be firmly around the neck and the other hand should support the bottom of the bottle.
- **Labeling:** Federal regulations require all containers must to be properly labeled with contents and contact. You can use the plastic ID labels when using chemicals in Petri dishes or beakers. For short term use, you may also write the chemical and contact information on a cleanroom wipe and locate it under the container. The NIST labeling guide has been provided for your reference. (See appendix for NIST labeling instructions, section 12 of this manual).

5.2 Personal Protective Equipment

Personal Protective Equipment (PPE) is mandatory when using chemicals. Special protective equipment is required for Hydrofluoric Acid (HF) processing and toxic gas bottle changes. Some chemicals and toxic gases require specialized PPE training, and this equipment cannot be used without proper training. The protective equipment used in the Cleanroom is listed below (Approved by NanoFab Safety Officer):

- Acid Aprons
- Latex gloves*
- Protective chemical sleeves
- High-wrist neoprene or nitrile gloves
- Face shield and safety glasses
- Self Contained Breathing Apparatus (SCBA-training and certification required every two years)
- Corrosive Protection Suit (Emergency Responders)

* Latex gloves used in the Cleanroom provide minimal chemical protection, and are primarily used to control human particulate contamination.

PPE Certification and testing:

- Chemical Gloves: You can check the chemical protective gloves for holes by filling the glove with nitrogen and immersing it into a water bath to see if any leaks are present. If a glove has holes or looks damaged, discard the glove and replace with new gloves. See Appendix for chemical protective glove resistance guide.

- SCBA Equipment: This equipment must be cleaned and tested every six months. This is coordinated by the NanoFab Safety Coordinator with NIST Fire Protection Group. This is conducted every six months to ensure the operability of the equipment.

PPE Training:

For PPE to be effective, proper use is essential. Below describes the procedures required to provide the maximum protection when using the supplied PPE.

- Chemical Resistant Apparel
  - **Adjustable face shield:** This is used with safety glasses. It can be adjusted to fit most head sizes. There are adjustment knobs on the straps that can be used to tighten the apparatus around the head. There are other adjustment knobs that can be used to make the face shield snug and secure. Do not use face shield if the adjustments are too loose, it may fall off the head or obscure the users vision.
  - **Chemical Gloves:** Choose gloves that fit over the protective latex glove, which are not too loose or too tight. A glove that is too loose will not provide the required dexterity needed to use the chemical process equipment (i.e. Timer buttons, tweezers, wet bench controls, etc).
- Toxic Gas Safety Equipment
  - **SCBA:** This equipment can only be used by trained individuals who have completed the required medical exam, and have completed fit testing and training. The certification for SCBA equipment is good for two years. The user of this equipment is required to view a video on Compressed Gas Safety (once per year) before the equipment can be used. The medical exam and the fit-testing can be arranged by the NanoFab Assistant Manager/Safety Coordinator, and is conducted on the NIST Gaithersburg Campus.

    Toxic Gas Bottle Training:
    - Your supervisor will keep a record of your required training and maintain the schedule you will be required to repeat the training.
    - The Supervisor will maintain a list of technicians performing this duty.
    - As per NFPA 318 Chapter 8, section 8.8.1 *Operators working with hazardous gases and handling hazardous compressed and liquefied gas containers shall be trained for that function.* Section 8.8.2 *Training shall be provided annually.*
    - Medical evaluations, fit testing and training for the SCBA equipment use is required every two years and the worker who completes the medical and fit testing will be issued a certificate from the Health Unit, and this must be kept on record by the supervisor. The schedule for the medical and fit test must be supported by the supervisor.
    - Note the date, location, and source of the training. If a quiz or certificate was available, print it out and attach it to the Supplemental Training form available from the Center office or the NanoFab Manager.
    - Sign the certification of training at the bottom of the page.
    - Have your supervisor initial each line after training is completed.
    - Save a copy and return the original to the Center Office.

5.3 Spills

Spill response procedures are provided in the NIST Gaithersburg Occupant Emergency Plan. These procedures apply to all chemical spills and oil spills that occur at the Gaithersburg site. Please keep the following points in mind should a spill occur:

- If a spill is found and the source is unknown:
  - Immediately clear the area and call the Fire Protection Group at x2222.
  - Report the location of the spill, your name, phone number, and any relevant information about the spill and access to the spill site. Stay on the line until the dispatcher has the information needed.

If you know the source of the spill, and you are familiar with the hazards of the spilled material:

- First ensure that you and all others in the area are safe.
- If it is safe to do so, remove all ignition sources.
- If you have the training and equipment, attempt to contain the spill.
- Call the Fire Protection Group x2222 and report the spill. Even if you do not need emergency response assistance, report the spill to the Fire Protection Group. The Fire Protection Group, in coordination with the Safety, Health, and Environment Division, must review each spill to ensure that it has been addressed properly. The spill clean-up materials must be properly disposed as chemical waste and the location of the spill must be cleared for occupancy.

If you have any questions regarding spill response, please contact the Safety, Health, and Environment Division at x5822 or x5818.

5.4 Eyewash Stations and Showers

The proper use of an eye wash station requires the user to activate the eyewash, and using the thumb and fingers, hold open the eyes, and rinse for several minutes. The user or buddy must call NIST Emergency Services at **x2222**. There are eyewash stations and showers available in the Cleanroom and the locations are listed below.

- **Eyewash stations**
  - At the ends of the chemical wet benches
  - In the class 1000 corridors immediately outside the cleanroom proper.

- **Safety Showers**
  - In the class 1000 corridors immediately outside the cleanroom proper.

5.5 MSDS

Material Safety Data information is provided in hard copy format, and is located in the main entrance in room D101. You can also find Up-to-date MSDS information on the internet by searching the following keywords: *MSDS, Material Safety Date Sheets, chemical name or on the chemical manufacturer website*. This data provides information about a particular chemical such as its hazards, storage procedures, first aid, long-term exposure, etc. There are many online sites that provide this information for free. Chemical vendors are required to provide MSDS information when purchasing chemicals. The NIST emergency response team has this information available from a CD and they have access to MSDS information from online.

5.6 Approval

New chemicals that enter the Cleanroom must be authorized by the NanoFab Management and must be accompanied by their MSDS information. This is to ensure compatibility with all current chemicals and processes.

5.7 HF Safety

Hydrofluoric acid (HF) is an extremely dangerous chemical. Because it is commonly used in the Cleanroom in various concentrations, *you may become exposed to HF even if you do not use it*. Therefore you must be aware of HF safety procedures. The areas where HF is used and stored are well identified by HF Acid danger signs. Stay alert and work carefully in these areas of the Cleanroom. If you are exposed to HF follow the procedures listed below.

1) Remove contaminated clothing.
2) Rinse with copious amounts of water.
3) Apply Calcium Gluconate gel, massage into affected area.
4) Call x2222 to report the incident.
5) Fill out an accident report.

5.8 Chemical Storage

Chemicals are to be stored in the properly designated areas, see Cleanroom layout for chemical storage areas. Use chemicals in an approved fume hood. The Cleanroom has separate chemical fume hoods for solvents (bases) and acids, and the hoods are labeled accordingly. Do not store incompatible substances next to each other. If you do not know what chemicals are incompatible; contact a Cleanroom staff member before using chemical. Never store a solvent next to an acid, because acid produces heat from an exothermic reaction. Never store chemicals in your locker.

5.9 Pregnancy

Users who may be pregnant are not restricted from using the NanoFab, but may want to discuss the situation with a NIST safety representative, their group leader, or the NanoFab manager. Some chemicals such as solvents and photoresist can be harmful to the unborn fetus.

5.10 Waste and Disposal/Satellite Accumulation Area

Chemical waste generated in the Cleanroom must be stored in a properly labeled container (see appendix for proper labeling) and placed in the designated storage areas under the fume hoods and or in the labeled pass-thrus. When the waste storage is full, contact the Cleanroom Staff (see contacts on page 14) so the waste can be properly disposed of. The chemical waste bottle(s) will be placed in a compatible chemical cabinet in the chemical storage room D106. The Cleanroom staff will contact NIST Safety and the waste chemicals will be retrieved for disposal from the Chemical Waste Satellite Accumulation Area (SAA) in room D107. The following link will provide information about the NIST SAA: Q:\Center_Office\Operations_Manual\04_Nanofab_Facility\042_User_Document_(originals)/SAA_at_NIST. The waste pick up request can be filled out on the NIST website at: http://winweb.nist.gov/ChemicalWaste/ChemWaste/chemwasteform.cfm

5.11 Chemical List (See Appendix)

6. Gas Safety (See appendix for NIST Compressed Gas Safety Information)

This section contains information on safety of gasses used in the NanoFab Cleanroom; however note that gas cylinder operations are to be performed by NanoFab Cleanroom staff exclusively.

6.1 Compressed Gas Delivery Emergency Response Program is in place in case of a catastrophic release of HPM (Hazardous Process Materials) upon delivery. This is the responsibility of the NIST Fire Protection Group. If there is a compressed gas delivery accidental gas release, leave the local area and contact **x 2222** (HAZMAT), and report the incident and the location.

6.2 Hazardous and Non-Hazardous Gases Used

The following compressed gases are used in the Cleanroom.

Gas	Assay	Hazard	Usage point	Location	Gas Cabinet ID
100% Silane	SiH4	Unpredictable, burns in moist air. Toxic.	LPCVD	B106	HH-1
5% Silane/Helium	SiH4+He	Unpredictable, burns in moist air. Toxic.	PECVD	B106	HH-9
Dichlorosilane	SiCl2H2	Corrosive, Toxic	LPCVD	B106	HH-3
Ammonia	NH3	Corrosive, Toxic	LPCVD,PECVD	B106	HH-5
Hydrogen	H2	Flammable	ATM Furnaces	B106	HH-8
Oxygen	O2	Supports combustion	ATM Furnaces, RIE, PECVD, LPCVD	B106, B105	NA
Sulfur Hexafluoride	SF6	Low toxicity level	RIE, PECVD, DRIE	B105, B106	HH-4
Trifluoromethane	CHF3		RIE	B105	HH-7
Nitrous Oxide	N2O	Asphyxiation	RIE, PECVD, DRIE	B105, B106	HH-2
Nitrogen	N2	Asphyxiation	Facility Wide	Facility Wide	NA
Forming Gas	N2/H2	Flammable	ATM Furnaces, RTP	B106,	HH-8
Octafluorocyclobutane	C4F8	Asphyxiation	Deep Silicon Etcher	B105	HH-7
Boron Trichloride	BCl3	Highly Toxic	Metal RIE	B105	HH-6
Chlorine	Cl2	Corrosive, Highly Toxic	Metal RIE, Metal ICP	B105	HH-6
Carbon Tetrafluoride	CF4	Asphyxiation	RIE	B105	HH-2
Argon	Ar	Asphyxiation	Sputter, ATM Furnaces, RTP	B104, B105, B106	NA

6.3 Cylinder Leak Check

Process gas cylinders should be checked for leaks before receiving delivery. This is typically done by the delivery outfit before loading the truck and on-site before receiving the gas delivery.

6.4 Toxic Gas Cylinder Change out

Toxic (and pyrophoric) gas cylinder change-out is a two-man operation. Both individuals are required to be properly trained (see section 5.2 in this manual) and must wear SCBA equipment during cylinder change-out. The hallways leading to the sub-fab area must be barricaded until the cylinder is installed. A call to the NIST Fire Protection Group must be placed, providing the information that a toxic gas cylinder change-out is in progress. A return call must be placed after the installation is completed.

6.5 SCBA Program

The requirements for using a Self Contained Breathing Apparatus at NIST are a medical exam, fit test, and usage training. This is coordinated by the NanoFab Safety Officer in

conjunction with the NIST Medical Unit, NIST Fire Protection Group and with the NIST Safety Office. The certification is good for two years.

6.6 Highly Toxic Gases Used

Currently, the Cleanroom has only two gases that are considered highly toxic, Boron Trichloride and Chlorine. These gases are used in the metal etching systems in room B105. If Chlorine odors are detected, evacuate the Cleanroom and contact a NanoFab staff member. If a staff member is not immediately available, call the HAZMAT Team at **x2222**, and report the odor.

Remember, when in doubt, GET OUT!

6.7 Toxic Gas Handling and Usage

Proper handling and training is required when using toxic gases. **All** gas cylinders are to be transported using and approved cylinder truck with attachable chain. Gas bottle hook-up must be done with two people and a Scott Pack SCBA if toxic gases are used. *All gases are to be handled by the Cleanroom staff only*. Users are not authorized to access the gas cabinets located in the sub-fab locations.

When opening a cylinder of process gas, just open the valve enough to get the gas pressure up, but **do not crank the valve all the way open**. When the valve is cranked wide open, it can be mistaken for a closed valve. Place appropriate signs for charged process gas lines inside the cabinets so that it is visible from the closed door position.

7. Nanoscale Material Safety

7.1 Overview

To ensure that the appropriate steps are taken to minimize the risk of exposure, a risk management program will be implemented. Elements of such a program will include the establishment of guidelines for installing and evaluating engineering controls (e.g., exhaust ventilation), the education and training of workers in the proper handling of nanomaterials (e.g., good work practices), and the development of procedures for selecting and using personal protective equipment (e.g., clothing, gloves, respirators).

7.2 Nanoparticle Safety Committee:

Nanoparticle Safety Committee Membership:
Andy Berglund, CNST
John Dagata, MEL
Bill Grosshandler, BFRL
Polly McCarty, NCNR
Kalman Migler, MSEL, Vice Chair
Dianne Poster, CSTL, Chair
Darwin Reyes, EEEL
John Small, CSTL
Glen Solomon, PL
TBD, Plant
TBD, Boulder Labs
TBD, SHED

7.3 Nanoparticle Safety Policy

The policy for nanoparticle safety is currently under development by NIST and the CNST.

8. Emergency Services

8.1 Fire Response

At NIST the emergency number for a fire in the lab or building is x2222.

8.2 Chemical Spills

Chemical spills at NIST can be reported to the Fire department at x2222. Be prepared to provide all pertinent information to the Fire Department such as **what**, **where** and **how much** was spilled.

8.3 Medical Emergencies

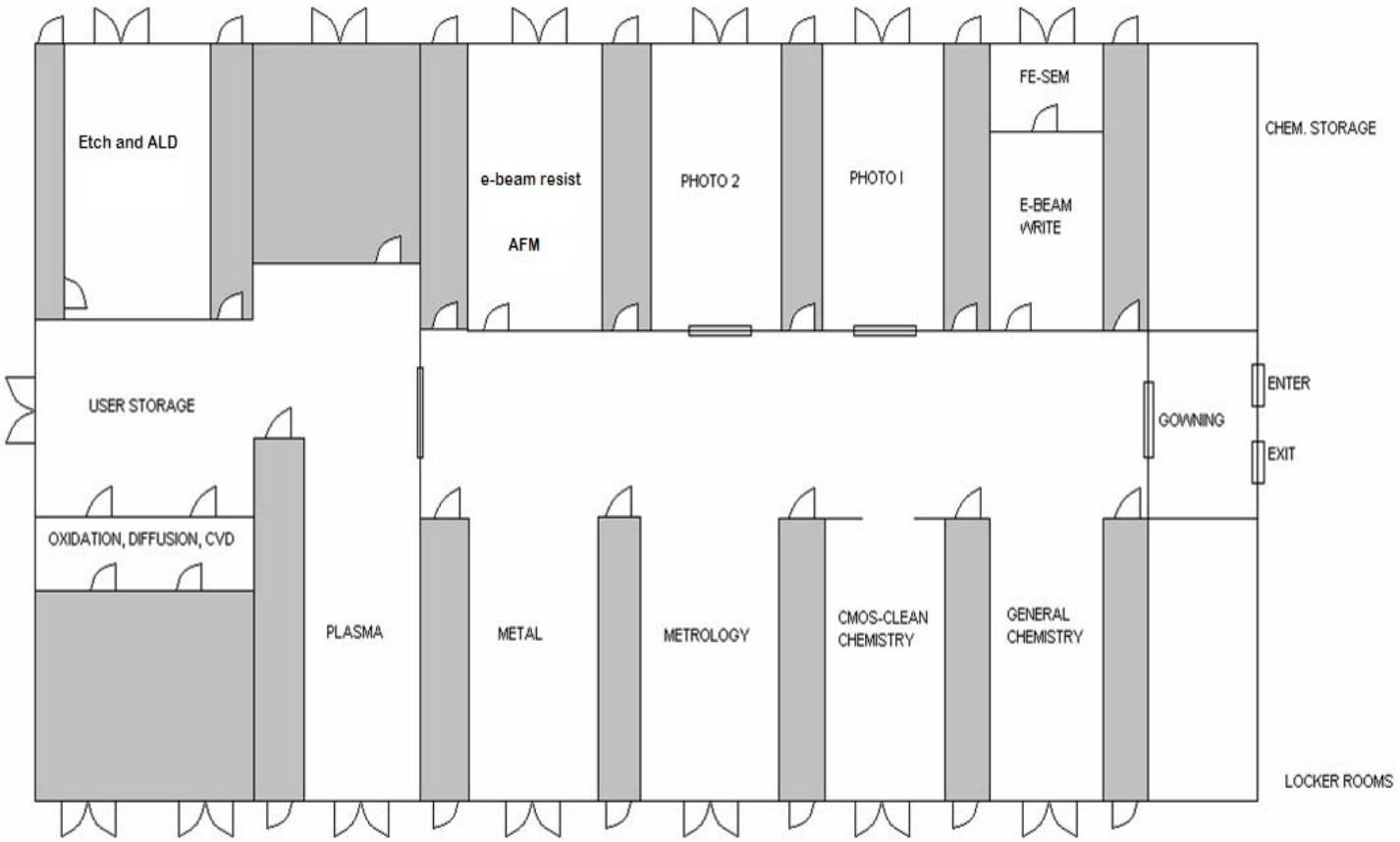
Medical emergencies such as chemical burns, inhalation injuries, falls, heart attacks, etc. require you to contact the NIST Fire Protection Group at x2222. If you are wearing the personal safety device, you may activate this device in the event of a medical emergency.

9. Contacts

9.1 Staff Directory

Robert Celotta	CNST Director	301-975-8001
Lloyd Whitman	NanoFab Manager (Acting)	301-975-8002
Russ Hajdaj	NanoFab Safety Officer	301-975-2699
Marc Cangemi	Process Engineer	301-975-5993
Richard Kasica	Process Engineer	301-975-2693
Lei Chen	Process Engineer	301-975-2908
Michael Hernandez	Physical Scientist	301-975-4590
Wade Hall	Admin Support	301-975-2096
Larry Buck	Electronics Technician	301-975-2242
Bill Young	Senior Equipment Maintenance Technician	301-975-4467
Dennis Myers	Safety Committee Member	301-975-5823
Mike Blackmon	Safety Committee Member	301-975-5822

10. Cleanroom Layout



11. Incident Report

NIST CNST NanoFab

Incident Report

To be completed by the NanoFab or Cleanroom user immediately after an incident involving equipment, facilities, other users, and/or safety related problems. This form is to be returned to the NanoFab Manager or NanoFab Staff Member upon completion. This is not an accident report form. This form is an information collection form that will assist NanoFab staff in making an accurate assessment of what occurred, and the appropriate corrective actions that must be taken.

Date: _____ Time: _____

Name: _____ Extension: _____

State fully how this incident occurred:

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(use back of form if more space is needed)

12. Appendix:

NIST Chemical Labeling Instructions:

CHEMICAL CONTAINER LABELING

1. PURPOSE

The purpose of this Health and Safety Instruction (HSI)* is to provide guidance for proper labeling of all chemical containers in the NIST. Although emphasis is placed on container labeling in labs, this HSI is equally applicable to all work areas and storage areas within the NIST, including those managed, operated, or used by NIST support/service units. Proper labeling will permit a person to quickly assess potential hazards and handling precautions, and to identify the owner of chemical substances in the workplace. This will facilitate safe handling, use, and disposal of chemicals in the NIST and benefit lab workers, safety representatives, support/service staff, and rescue personnel.

* Acronyms used herein are defined at the end of this document.

2. ACKNOWLEDGEMENT

NIST has adopted the National Fire Protection Association (NFPA) Hazard Identification System for labeling chemicals. The NFPA system uses a color code to signify the type of hazard and a numerical rating to indicate the severity of the hazard. The complete system is described in NFPA 704, Standard for the Identification of the Fire Hazards of Materials for Emergency Response, 2001.

3. INTRODUCTION

The OSHA Hazard Communication Standard (29CFR1910.1200) and Occupational Exposure to Hazardous Chemicals in Laboratories Standard (29CFR1910.1450) require that all workers be apprised of the hazards of the chemicals in their workplaces through the use of a written Hazard Communication Program, a written Chemical Hygiene Plan, proper labeling of containers, use of Material Safety Data Sheets (MSDSs), and appropriate training. HSI 7 documents NIST's Hazard Communication Program and NIST's Chemical Hygiene Plan is given in HSI 20. This HSI (15) specifies the procedures to be followed by all NIST lab workers (employees, guest researchers, research associates, faculty and intergovernmental appointees, contractors, students, etc.) and support/service staff to comply with the labeling requirements of the Hazard Communication Standard, and to promote safe handling of chemicals in our workplace as a result of clear communication of potential hazards. The procedures outlined herein also help satisfy certain regulations promulgated by the EPA. Every effort has been made to simplify this labeling procedure while retaining essential label data. A labeling guide is provided to facilitate the labeling task.

4. SCOPE

This HSI applies uniformly to all NIST labs, work areas, and storage areas in Gaithersburg and Boulder as specified below:

- chemical substances in all forms (liquids, gases, solids, and mixtures thereof) and conditions (new, old, excess, diluted, used, spent, waste, synthesized, samples, etc.) are covered by this HSI;

5. OBTAINING NFPA HAZARD RATINGS

The NFPA numerical ratings for chemicals can be found at the following:

a. Chemwatch – http://nist.chemwatch.us/ -type in the chemical name,

b. On most Material Safety Data Sheets (MSDS), and.

c. If you cannot find the numerical ratings for a chemical using one of the aboce methods, contact the Safety Health and Environmental Division (SHED) x5818 in Gaithersburg.

6. PROCEDURES

All chemicals that are used or stored at NIST must be labeled with one of the following:

a. NIST Chemical Owners Name (The CNST is the owner of most chemicals used in the NanoFab Cleanroom).

b. NIST Multipurpose Chemical Label.

7. DEFINITIONS AND ACRONYMS

ACGIH - American Conference of Governmental Industrial Hygienists.

CERCLA - Comprehensive Environmental Response, Compensation, and Liability Act (Superfund): implemented by the U.S. Environmental Protection Agency (EPA).

CFR - U.S. Code of Federal Regulations.

EPA - U.S. Environmental Protection Agency.

HSI - Health and Safety Instruction, issued by the Occupational Health and Safety (OHS) Division of the NIST, U.S. Department of Commerce. Note: HSIs will be used to update and replace all SPGs (Safety Program Guides) previously issued by the NIST. "HSI" and "SPG" will be used interchangeably until all SPGs have been replaced.

LC_{50} - The Median Lethal Concentration of a substance, administered by continuous inhalation in a prescribed manner for a given period of time, that is most likely to kill 50% of a group of animals within a specified time under test conditions. Specific terms and values are given in table 5.

LD_{50} - The Median Lethal Dose of a substance, administered orally or by continuous contact in a prescribed manner for a given period of time, that is most likely to kill 50% of a group of animals within a specified time under test conditions. Specific terms and values are given in table 5.

MASC - Mountain Administrative Support Center, U.S. Department of Commerce.

MSDS - Material Safety Data Sheet.

NIST - National Institute of Standards and Technology, U.S. Department of Commerce.

NFPA - National Fire Protection Association.

OSHA - Occupational Safety and Health Administration, U.S. Department of Labor.

PEL - The Permissible Exposure Limits established by OSHA, specifying allowable concentrations of air contaminants in the work environment. PELs may be given as a person's average exposure--a Time Weighted Average (TWA)--to airborne contaminants in any 8-hour work shift of a 40-hour workweek, or as ceiling values that are not to be exceeded. PELs are expressed as ppm (by volume) of vapor or gas in air, or as mg of chemical substance per cubic meter of air. Standards are given in 29CFR1910.1000, Subpart Z.

PLNR - PRECAUTIONARY LABELING NOT REQUIRED: signal words on the green NIST label.

SCF - Standard Cubic Feet, the volume occupied by a gas at 1-atmosphere pressure and 21.1°C (70°F).

TLV - The Threshold Limit Values established by the ACGIH, recommending allowable concentrations of airborne contaminants for avoidance of adverse health effects. TLVs may be given as a Time Weighted Average (TWA) concentration for a normal 8-hour workday and a 40-hour workweek, as a Short Term Exposure Limit (STEL) which is the maximum 15-minute TWA concentration allowed, or as a ceiling concentration that should not be exceeded during a workshift. TLVs are expressed in the same units as PELs. TLVs are listed in the ACGIH booklet entitled "Threshold Limit Values and Biological Exposure Indices," Cincinnati, Ohio (updated annually).

Container Capacity Limitations* for Flammable and Combustible Liquids Stored in the Lab.

	CONTAINER MATERIAL		
	Glass or Approved Plastic	**Metal****	**Safety Cans**
Flammable Liquids			
Class IA	0.47l (1 pint)†	3.79l (1 gallon)	7.57l (2 gallons)
Class IB	0.95l (1 quart)†	18.93l (5 gallons)	18.93l (5 gallons)
Class IC	3.79l (1 gallon)	18.93l (5 gallons)	18.93l (5 gallons)
Combustible Liquids			
Class II	3.79l (1 gallon)	18.93l (5 gallons)	18.93l (5 gallons)
Class III	3.79l (1 gallon)	18.93l (5 gallons)	18.93l (5 gallons)

* Limitations apply to new, excess, used, or waste liquids.

** Excludes DoT metal drums.

† The use of larger glass or plastic containers requires an exemption from the NIST/MASC Safety Office and must meet OSHA 29CFR1910.106 requirements. If the use of larger glass containers [up to 3.79l (1 gallon)] is permitted, they must be stored in approved carriers or containers capable of holding the contents of the glass container.

Definitions

Flammable Liquid: A Class I liquid having a flash point below 37.8°C (100°F) and a vapor pressure not exceeding 276 kPa (40 psia) at 37.8°C (100°F).

Class 1A liquids have flash points below 22.8 °C (73 °F) and boiling points below 37.8C (100°F).
Class 1B liquids have flash points below 22.8°C (73 °F) and boiling points at or above 37.8°C (100°F).
Class 1C liquids have flash points at or above 22.8° C (73°F) and below 37.8°C (100°F).

Combustible Liquid: A liquid having a flash point at or above 37.8°C (100°F).

Class II liquids have flash points at or above 37.8°C (100°F) and below 60°C (140°F).
Class IIIA liquids have flash points at or above 60°C (140°F) and below 93.4°C (200°F).
Class IIIB liquids have flash points at or above 93.4°C (200°F).

Flash Point: The minimum temperature at which a liquid within a test vessel gives off vapor in sufficient concentration to form an ignitable mixture with air near the surface of the liquid, as determined by appropriate ASTM test procedures and apparatus.

Source: Adapted from NFPA Code 45 (August 1991) and OSHA 29CFR1910.106 (July 1991).

Cross Reference of Hazard Codes for the NIST Labeling Guide.

FLAMABILITY

Label Color	Label Signal Words	Flash Point	OSHA/NFPA Class. (NFPA Rating)**	CERCLA Rating
Red	DANGER	F.P. <-6.7°C (F.P. <20°F)	IA(4), IB(3)	3
Orange	WARNING	-6.7°C≤F.P <37.8°C (20°C≤F. P. <100°F)	IA(4), IB(3), IC(3)	3
Yellow	CAUTION	37.8°C ≤F. P. <93.3°C (100°F ≤F. P. <200°F)	II(2), IIIA(2)	2
Green	PLNR*	F. P. ≥ 93.3°C (F. P.≥<200°F)	IIIB(1)	1

* PLNR = PRECAUTIONARY LABELING NOT REQUIRED.
** Many manufacturers use the NFPA hazard rating system and flammable/combustible liquid classification system.

REACTIVITY

Label Color	Label Signal Words	NFPA Rating (CERCLA Rating)	Comments
Red	DANGER	4[3]	Will readily explode or detonate or decompose explosively at room temperature and pressure.
Orange	WARNING	3[3] and 2[2]	Normally unstable and will readily undergo violent chemical change (without detonation), or will detonate or explosively decompose with strong initiator, or will react explosively with water.
Yellow	CAUTION	1[1]	Normally stable but becomes unstable at elevated temperatures and pressures, or reacts with water with nonviolent energy release.
Green	PLNR*	0[0]	Normally stable, even under fire conditions, and does not react with water. Not likely to react in a manner that will produce harmful results.

* PLNR = PRECAUTIONARY LABELING NOT REQUIRED.

HEALTH HAZARD-Skin Absorption

Label Color	Label Signal Words	LD_{50}**	Comments
Red	DANGER	$LD_{50} \leq 200$ mg/kg	A single prolonged exposure, or rapid absorption, may be fatal.
Orange	WARNING	$200 < LD_{50} \leq 1000$ mg/kg	A single prolonged exposure, or rapid absorption, may be harmful. Repeated exposure may be fatal.
Yellow	CAUTION	-----	Repeated exposure may result in absorption of harmful amounts.
Green	PLNR*	-----	Not likely to be harmful.

* PLNR = PRECAUTIONARY LABELING NOT REQUIRED.

** LD_{50} (Median Lethal Dose) values are given in milligrams of chemical substance per kilogram of body weight when administered by continuous contact for 24 hours (or less if death occurs within 24 hours) with the bare skin of albino rabbits weighing between 2 and 3 kilograms each.

HEALTH HAZARD-Inhalation

Label Color	Label Signal Words	LD_{50}#	Comments
Red	DANGER	$LC_{50} \leq$ 200 ppm for 1 hr (gases & vapors) $LC_{50} \leq$ 2mg/liter for 1 hr (fumes, mists, dusts)	A single short exposure may cause serious adverse effects, even death.
Orange	WARNING	$200 < LC_{50} \leq 2000$ ppm for 1 hr (gases & vapors) $2 < LC_{50} \leq 20$ mg/liter for 1 hr (fumes, mists, dusts)	A single short exposure may cause adverse effects. Prolonged exposure may cause death.
Yellow	CAUTION	---------	A single exposure may cause irritation or asphyxia. Prolonged exposure may cause adverse effects.
Green	PLNR*	---------	Not likely to cause adverse effects.

* PLNR = PRECAUTIONARY LABELING NOT REQUIRED.

LC_{50} (Median Lethal Concentration) values are given in parts per million by volume of chemical gas or vapor in air--or in milligrams of chemical substance per liter of air for toxic mists, fumes, or dusts--when administered by continuous inhalation for one hour (or less if death occurs within one hour) to albino rats weighing between 200 and 300 grams each.

HEALTH HAZARD-Ingestion

Label Color	Label Signal Words	LD_{50}**	Comments
Red	DANGER	$LD_{50} \leq$ 50 mg/kg	Highly toxic. A single oral dose may be fatal.
Orange	WARNING	$50 < LD_{50} \leq$ 500 mg/kg	Toxic. A single oral dose can be harmful, even fatal.
Yellow	CAUTION	-----	Slightly toxic. A single oral dose may be harmful.
Green	PLNR*	-----	A single oral dose is not likely to be harmful.

* PLNR = PRECAUTIONARY LABELING NOT REQUIRED.

** LD_{50} (Median Lethal Dose) values are given in milligrams of chemical substance per kilogram of body weight when administered orally to albino rats weighing between 200 and 300 grams each.

HEALTH HAZARD-Eye/Skin Contact

Label Color	Label Signal Words	Comments
Red	DANGER	Corrosive. A single short exposure may cause severe burns or blindness.
Orange	WARNING	Severe irritation may occur. Prolonged exposure may cause burns. Repeated exposure may cause strong allergic reaction.
Yellow	CAUTION	Slight to moderate irritation may occur upon prolonged exposure. Repeated exposure may cause allergic reaction.
Green	PLNR*	Not likely to cause irritation or allergic reaction.

* PLNR = PRECAUTIONARY LABELING NOT REQUIRED.

HEALTH HAZARD-Overall**

Label Color	Label Signal Words	NFPA Rating [CERCLA Rating]	Comments
Red	DANGER	4[3], 3[3]	Very short term exposure can cause death or major residual injury, even if medical attention is received promptly.
Orange	WARNING	2[2]	Short term exposure can cause severe and lasting health problems.
Yellow	CAUTION	1[1]	Significant exposure can cause undesirable health effects.
Green	PLNR*	0[0]	No known adverse health effects.

* PLNR = PRECAUTIONARY LABELING NOT REQUIRED.

** In the absence of detailed test data in each of the four subcategories of HEALTH HAZARD (Skin Absorption, Inhalation, Ingestion, and Eye/Skin Contact), the NFPA or CERCLA Ratings can be used as a reasonable guide to the overall HEALTH HAZARD assessment and its associated label color.

NIST Compressed Gas Safety Procedures

COMPRESSED GAS CYLINDERS

1. PURPOSE

This Health and Safety Instruction is issued to provide guidelines and a set of general rules pertaining to safety in the storage, handling and use of compressed gas cylinders.

2. INTRODUCTION

a) Using compressed gas cylinders in laboratories presents many problems not generally encountered in industrial use. These problems include the variety of flammable, toxic and radioactive materials and special mixtures with properties that are frequently unfamiliar to the researcher. The tendency of laboratory personnel is to modify, adapt, and repair cylinder valves and regulators themselves, rather than to leave such work to the supplier or specially trained personnel. Incorporating a cylinder into an experimental apparatus so that foreign materials can enter the cylinder or so that the cylinder or systems may be subjected to extreme pressures is an extremely hazardous practice that unfortunately has been fairly common in some research laboratories.

b) Compressed gas cylinders can be safely used in laboratories if the NFPA codes and following general rules (as published in the CRC Handbook of Laboratory Safety) are complied with completely during cylinder receiving operations, storage, transportation to the laboratory or other use point, usage and return of empty cylinders.

3. LECTURE BOTTLES

a) Using cylinders other than lecture bottles is encouraged. Many suppliers will no longer accept lecture bottles for return and NIST must pay a high cost to dispose of them.

b) If you must use a lecture bottle, check with the suppliers and use one who will allow you to return it. Even though the returnable lecture bottle may cost more, not having to pay the disposal cost will offset the high purchase cost.

4. GENERAL RULES

a) Know the Gas and its Properties: Researchers should know the properties and hazards of the gases they are going to use. Knowledge of the gases properties is essential to laboratory operations due to the unusual uses to which gases may be put, as well as the uncommon gases or special gas mixtures used. Not only should the flammability, corrosiveness or oxidation potential be known but also the physiological properties must be kept in mind--such as toxic, anesthetic, or irritating qualities. Two examples are carbon monoxide, which is both toxic and flammable, and hydrogen sulfide, which is toxic and has the ability to desensitize the sense of smell. A copy of the gases' Material Safety Data Sheet (MSDS) should be available for review by the researchers and emergency services personnel.

b)Labeling Cylinders/ Cylinders with Unknown Contents: All compressed gases cylinders and liquefied gas containers are to be appropriately labeled in accordance with Section 6 of HSI No. 15, Chemical Container Labeling (see 6.8 Special Labels). More specifically, compressed gas cylinders and liquefied gas containers **must** bear some legible marking, tag or label to clearly indicate their contents (e.g., hydrogen, fluorine, propane, etc.) **AND** an appropriately color-coded NIST *Owner and Date* label. Do not remove this identification marking from empty cylinders as this might present a hazard to the supplier. Also, do not rely on color codes for cylinder content identification as this varies from supplier to supplier, and many persons are color blind.

5. CYLINDERS CONTAINING TOXIC GAS

a) What are Toxic Gases? Toxic gases are those with an NFPA 704[1[1]] Health Hazard Rating 3 or 4 or having a Health Hazard Rating of 2 with no physiological warning properties.

b) Storing Toxic Gases: When new storage areas are designed or existing ones are renovated, toxic gases must be stored in continuously mechanically ventilated gas cabinets. Toxic gases with a Health Hazard Rating of 4 will require a gas detection system.

c) Using Toxic Gases: When renovating or making major modification to a lab that uses or will use a toxic gas, the cylinders must be stored in a continuously mechanically ventilated hood or gas cabinet. No more than three (3) of these cylinders may be

[1[1]] NFPA 704: Standard for the Identification of the Fire Hazards of Materials for Emergency Response, 1996 Edition

stored in a hood or gas cabinet. A listing of chemicals and their NFPA Health Hazard Ratings can be found at http://www.orcbs.msu.edu/chemical/nfpa/nfpa.html

6.CYLINDER STORAGE AND USE

a) Store Cylinders Appropriately: Store and use cylinders in ventilated areas away from heat and ignition sources. Segregate flammable gases from other gases, particularly oxygen. Limit the quantity stored in one location. Cylinders containing gases under high pressure could very quickly render an area unsafe if the large volume of gas should be released. Most cylinders, except those in toxic gas service, are equipped with safety relief devices of the rupture disk or spring-loaded type. The rupture disc type pressure-relief devices may function prematurely if cylinders are heated to a temperature in excess of 52 C (125 F) and release the entire content of the cylinders. Also, cylinders containing low vapor pressure liquids could become liquid filled at elevated pressures and burst. If a cylinder must be heated, this should be done in a very well thermostated water bath heated to no more than 52 C (125 F). However, this is a hazardous procedure at best, and should be avoided, especially with full cylinders.

b) Securely Fasten Cylinders: Whether in use or being stored, all cylinders must be securely fastened. If a cylinder should fall or roll off a bench, the regulator or valve might break off and release a large quantity of gas. This may cause the cylinder to pinwheel, which can injure employees or damage equipment. Another danger is that the valve could shear off and the cylinder might "rocket" like a projectile due to the sudden release of pressure. The storeroom stocks supports (clamps) available for securing cylinders to a bench, a wall, etc. Where cylinders must stand away from a wall or bench, cylinder stands for large (6" to 9 1/4"diameter cylinders), small (4" to 6" diameter cylinders) and lecture bottle (2" diameter) are commercially available. Although there are innumerable commercial holders, stands, etc., available for supporting cylinders, a length of chain, cable or rope can also be used to secure a cylinder to a work bench or other fixed object. The main consideration is that cylinders must be adequately secured.

c) Keep Caps on Cylinders Not in Use: Caps used for valve protection should be kept on the cylinder except when the cylinder is in use. Removing the cap when **not** using the cylinder, exposes the valve to being damaged and leaking.

d) Maximum Number of Cylinders in a Lab: The following table from NFPA 45 *Standard on Fire Protection for Laboratories Using Chemicals, 1996 Edition* gives the maximum number of compressed or liquefied gas cylinders that may be place in a laboratory work area.

Maximum Number of Compressed or Liquefied Gas Cylinders in a Laboratory Work Area

	Flammable or Oxidizing Gases		Liquefied Flammable Gases		Gases with Health Hazard Rating of 3 or 4
	Sprinklered Space	Nonsprinklered Space	Sprinklered Space	Nonsprinklered Space	Sprinklered or Nonsprinklered Space
Max. No. of cylinders per 46.5 m^2 (500 ft^2) or less	6	3	3	2	3

e) Do Not Tamper with Cylinders: Never tamper with cylinder valve, safety plugs or packing nuts. Tampering with these could create a leak and a potentially hazardous atmosphere. If a hazardous condition is created in the laboratory, exit the lab and call for emergency help. There have been fatalities in laboratories caused by unfamiliarity with valves. In one instance, the safety nut was confused with an outlet cap, which is frequently installed on the outlet, and the safety nut was completely removed. Note that the safety nut connects directly to the valve inlet (pressure side) and once removed, the flow of gas cannot be stopped.

f) Leaking Cylinders: Leaking cylinders should be marked as “leakers” and removed to an open area until picked up by the supplier. Do not put unmarked leaking cylinders among the empties. DOT transportation regulations forbid shipping leaking containers by common carrier. Note: Call X2222 (X7777 in Boulder) for assistance with leaking cylinders.

g) Do Not Strike Arcs on Cylinders: Do not strike an electric arc on cylinders. This rule is directed primarily to industrial users, where inert gases are used for shielded arc welding. It is very tempting to test the arc on the large metal surface. Arc burns, however, not only are stress raisers, but due to metallurgical changes, could cause the heat affected portion of the cylinder to become brittle.

h) Use Compressed Gases with Appropriate Equipment: Only use regulators that are suitable for the cylinder. Proper mating hardware should fit; do not force the connection. Do not use homemade adapters. The importance of this rule cannot be overemphasized. Accidents have occurred because of attaching flammable gas regulators to oxygen cylinders, improperly identifying the contents of a cylinder, and so forth. American National/Compressed Gas Association Standard for Compressed Gas Cylinder Valve Outlet and Inlet Connections lists the various standard connections for compressed gases. The connections listed are classified into four thread divisions. There are left and right-hand threads and internal and external threads, plus some pipe threads and yoke type connections. The various gases are assigned to connections so that hazardous interconnections cannot be made. Generally speaking, left-hand threads are reserved for flammable gases and right-hand threads for nonflammables. There are a few exceptions made necessary by previous practice. Almost always, hazardous connections cannot be made except by homemade adapters or by forcing the connection.

i) Use of Cylinder Regulators: Cylinders contain pressures greater than the pressures which most laboratory equipment can withstand, even steel or nonferrous tube. Always use a regulator with high-pressure cylinders (above 500 psi). The inadvertent closing of a vent valve or stopcock or the plugging of a line or mercury trap could cause a violent failure of the apparatus. There are fine needle valves available which can reduce the flow of gas from the high-pressure cylinder to a few bubbles a minute. Such valves are not regulators and the design of any equipment used with them must keep this fact in mind. Use needle valves only with low-pressure cylinders (below 500 psi). Valves are only flow regulators, not pressure regulators.

j) Close Cylinder Valves When Not in Use: Do not stop the gas flow from cylinders overnight by only backing off on the regulators. Even the best of regulators can develop seat leaks and allow excessive pressures to develop in using equipment. Closing the cylinder valve will eliminate this hazard. If this rule is followed meticulously, any question as to the position of a cylinder valve in an emergency is removed. Finally, no foreign materials can enter the cylinder if through leakage or other malfunction the cylinder pressure should become lower than the pressure in some other part of the apparatus.

k) Close Valves on Empty Cylinders and Mark the Cylinder Empty or "MT": If cylinders are returned to the supplier with the valve open, the interior will become contaminated with atmospheric air and moisture. Such cylinders cannot be used for high purity gases without extensive reconditioning. If the cylinder had contained such materials as anhydrous hydrogen chloride, or chlorine, this resultant humid atmosphere would corrode the cylinder very rapidly. Empty cylinders should be so marked "MT" and stored separately to avoid returning full cylinders to the supplier or sending empties to the laboratories or other use point.

l) Never Attempt to Refill a Cylinder: It is very tempting to refill your own small cylinders from large ones by interconnecting them with high pressure tubing. There are a number of reasons why this practice is hazardous. The cylinder being filled may have a lower working pressure than the large cylinder. Filling too rapidly can result in extremely high cylinder temperatures which could damage the valve. The cylinder being filled may contain a residue of a reactive material. It is extremely difficult to completely purge a cylinder. For cylinders containing liquids, DoT prescribes filling weights which allow for a vapor space at temperatures and pressures for which the safety device functions. If these weights are exceeded, the cylinders may become liquid-full at room temperatures and fail. Finally, at least one supplier of laboratory gases uses a very lightweight welded, thin-wall aluminum, or one-time use cylinder (i.e., DoT 39) which is classified as non-refillable by DoT. For safety reasons such a single-use cylinder must be discarded after use the same as the common aerosol spray cans.

7. TRANSPORTING AND HANDLING CYLINDERS

a) Handle Cylinders Carefully: Cylinders are primarily shipping containers and as such are constructed to be as light as possible consistent with safety, durability and pressurization requirements. Cylinders should be moved with great care, preferably strapped to a cart. As the valve assembly is the weakest part of the cylinder, avoid striking the valve against anything. Rough handling or abuse could seriously weaken the cylinder and render it unfit for further use.

b) Transport Cylinders Safely: Transport large cylinders only on a wheeled cart. Do not slide or roll them even one at a time, since it is easy to lose control of a cylinder while rolling or dragging no matter how much practice a person might have. If one falls, it could land on the foot. Additionally, avoid dragging cylinders as this procedure introduces other manual handling hazards. Mishandling of cylinders in transit is the cause of many pulled muscles, back injuries and foot injuries.

NFPA HEALTH HAZARD RATING SYSTEM*

A health hazard is any property of a material which, either directly or indirectly, can cause injury or incapacitation, either temporary or permanent, from exposure by contact, inhalation, or ingestion.

Rating	Description
4	Materials which on very short exposure could cause death or major residual injury even though prompt medical treatment is given, including those which are too dangerous to be approached without specialized protective equipment. This degree includes: materials which can penetrate ordinary rubber protective clothing; materials which under normal conditions or under fire conditions give off gases which are extremely hazardous (i.e., toxic or corrosive) through inhalation or contact with or absorption through the skin. Examples of compressed and/or liquefied gases of this degree include: Cyanogen, Fluorine, Hydrogen Cyanide and Hydrogen Fluoride.**
3	Materials which on short exposure could cause serious temporary or residual injury even though prompt medical treatment is given, including those requiring protection from all bodily contact. This degree includes: materials giving off highly toxic combustion products; materials corrosive to living tissue or toxic by skin absorption. Examples of compressed and/or liquefied gases of this degree include: Anhydrous Ammonia, Chlorine, Diborane, Ethylamine, Hydrogen Bromide, Hydrogen Chloride, Hydrogen Sulfide, Methylamine, Methyl Bromide and Phosphine.**
2	Materials which on intense or continued exposure could cause temporary incapacitation or possible residual injury unless prompt medical treatment is given, including those requiring use of respiratory protective equipment with independent air supply. This degree includes: materials giving off toxic combustion products; materials giving off highly irritating combustion products; materials which either under normal conditions or under fire conditions give off toxic vapors lacking warning properties. Examples of compressed and/or liquefied gases of this degree include: 1,3-Butadiene, Carbon Monoxide, Dimethyl Ether, Ethyl Chloride, Ethylene Oxide, Formaldehyde, Methyl Chloride, Methyl Mercaptan, Sulfur Dioxide, Tetrafluoroethylene, Trimethylamine, Vinyl Bromide and Vinyl Chloride.**
1	Materials which on exposure would cause irritation but only minor residual injury even if no treatment is given, including those which require use of an approved canister type gas mask. This degree includes: materials which under fire conditions would give off irritating combustion products; materials which on the skin could cause irritation without destruction of tissue. Examples of compressed and/or liquefied gases of this degree include: Acetylene, r.-Butane, iso-Butane, 1-Butene, 2-Butene,Cyclopropane, Ethane, Ethylene, Methane, Natural Gas, iso-Pentane, Propane, Propylene and Vinyl Fluoride.**

Appendix B-1

FLAMMABILITY CHARACTERISTICS OF COMMON COMPRESSED AND LIQUIFIED GASES

This list is not inclusive or exhaustive. Practically all compressed and liquefied gases present varying health hazards to personnel. Therefore, users are urged to seek additional information from reliable references to adequately assess the reactivity or toxicity of the material. Contact the Safety Office in Gaithersburg (X5818) or the MASC Safety Office in Boulder (X3948) for additional information, as needed.

GAS	FLAMMABLE RANGE (if Flammable, percent by vol.)	REFERENCE SOURCE	GAS	FLAMMABLE RANGE (if Flammable, percent by vol.)	REFERENCE SOURCE
Acetylene	2.5 - 82	MGD	Hydrogen Cyanide[1]	5.6 - 40	325M, 627
Allene[1]	1.5 - 11.5	MGD	Hydrogen Fluoride	(a)	
Ammonia[1]	15 - 28	MGD	Hydrogen Iodide	(a)	

Arsine[1]	(b)	MGD	Hydrogen Selenide[1]	(b)	
Boron Trichloride	(a)	MGD	Hydrogen Sulfide	4 - 44	325M, 627
Boron Trifluoride	(a)	MGD	Ketene	(b)	
1,3-Butediene[1]	2 - 12	627	Methane	5 - 15	325M, 627
n-Butane[1]	1.6 - 8.4	325M	Methylacetylene[1](Propyne)	2 - 11.1	325M
iso-Butane[1]	1.8 - 8.4	325M	Methylamine[1]	4.9 - 20.7	325M
I-Butene[1]	1.6 - 10	627, 325M	Methyl Bromide[1]	10 - 16	325M
2Butene	1.7 - 9.7	627	3 - Methyl-1-butene[1]	1.5 - 9.1	325M, 627
Carbon Monoxide	12.5 - 74	627	Methyl Chloride[1]	8.1 - 17.4	325M
Carbonyl Chloride (Phosgene)	(a)		Methyl Fluoride[1]	(b)	
Carbonyl Fluoride	(a)		Methyl Mercaptan[1]	3.9 - 21.8	325M
Carbonyl Sulfide[1]	12 - 29	325M	2-Methylpropene	1.8 - 9.6	325M, 627
Chlorine	(a)		Natural Gas	3.8/6.5 - 13/17	325M
Chlorine Dioxide	(a)		Nitric oxide	(a)	
Chlorine Trifluoride	(a)		Nitrogen Dioxide	(a)	
1-Chloro-l,l-Difluorethane[1]	9 - 14.8	MGD	Nitrogen Trioxide	(a)	
Chlorotrifluoroethylene[1]	8.4 - 38.7	MGD	Nitrogen Trifluoride	(a)	
Cyanogen[1]	6 - 32	MGD	Nitrosyl Chloride	(a)	
Cyanogen Chloride[1]	(a)		Oxygen	(a)	
Cyclopropane[1]	2.4 - 10.4	MGD, 627	Oxygen Difluoride	(a)	
Deuterium	5 - 75	325M	Ozone	(a)	
Diazomethane	(b)		iso-Pentane[1]	1.4 - 7.6	325M
Diborane	0.8 - 88	325M, 627	Perchloryl Fluoride	(a)	
1,1-Difluoroethane[1]	3.7 - 18	MGD	Phosphine	(c)	
1,1-Difluoroethylene[1]	5.5 - 21.3	MGD	Propane	2.1 - 9.5	325M, 627
Dimethyl Ether[1]	3.4 - 27	325M, 627	Propylene[1]	2.0 - 11.1	325M
2,2-Dimethytpropane[1]	1.4 - 7.5	325M, 627	Selenium Hexafluoride	(a)	
Ethane	3.0 - 12.5	325M, 627	Silane	(c)	

Ethytacetylene[1]	(b)		Silicon Tetrafluoride	(a)	
Ethylamine[1]	3.5 - 14	325H	Stibine	(b)	
Ethyl Chloride[1]	3.8 - 15.4	325M	Sulfur Dioxide	(a)	
Ethylene	2.7 - 36	325M, 627	Sulfur Tetrafluoride	(a)	
Ethylene Oxide[1]	3 - 100	MGD	Sulfuryl Fluoride	(a)	
Fluorine	(a)		Tetrafluoroethylene[1]	10/11 - 50/60	MGD, 325M
Formaldehyde	7 - 73	325M	Tetrafluorohydrazine[1]	(b)	
Germane	(b)		Trimethylamine[1]	2 - 11.6	MGD, 325M
Hexafluoroacetone	(a)		Vinyl Bromide[1]	9 - 15	325M
Hydrogen	4 - 75	325M, 627	Vinyl Chloride[1]	3.6 - 33	325M, 627
Hydrogen Bromide	(a)		Vinyl Fluoride[1]	2.6 - 21.7	MGD
Hydrogen Chloride	(a)		Vinyl Methyl Ether[1]	(b)	

[1]Liquefied Gases

Notes on Flammable Range:(a) - Not flammable,(b) - Flammable but range not reported, (c) - Spontaneously flammable

Reference source for flammable ranges: 325-NFPA 325 - *Guide to Fire Hazard Properties of Flammable liquids, Gases, and Volatile Solids*

627-U.S. Bureau of Mines Bulletin 627, *Flammability Characteristics of Combustible Gases and Vapors*

MGD-*Matheson Gas Data Book*

Chemical Glove Resistance Guide

Chemical Name	NFPA Health Rating	Nitrile	Natural Rubber Latex	Recommended Alternate Material
ACETALDEHYDE	3	P	G	
ACETIC ACID (GLACIAL)	3	F	G	
ACETIC ANHYDRIDE	3	F	G	
ACETONE	1	F	G	
ACETONITRILE	2	F	F	Butyl (E)
ACRYLIC ACID	3	G	G	
AMMONIUM ACETATE		E	E	
AMMONIUM CARBONATE		E	E	
AMMONIUM FLUORIDE, 30-70%	3	E	E	
AMMONIUM HYDROXIDE,30-70%		E	E	
AMMONIUM HYDROXIDE, <30%		E	E	
AMYL ALCOHOL	1	E	G	
ANILINE	3	F	G	
AQUA REGIA		P	P	Neoprene (F)
AZT			G	
BENZALDEHYDE	2	P	F	Butyl (E)
BENZENE	2	F	P	Viton (G)
BORIC ACID		E	G	
BROMOPROPIONIC ACID		F	G	
BUTYL ACRYLATE	2	P	P	Teflon (G)
BUTYL CELLUSOLVE		G	G	
CALCIUM HYDROXIDE		E	E	
CARBON DISULFIDE	3	G	P	
CARBON TETRACHLORIDE	3	P	P	Viton (G)
CHLOROBENZENE	2	P	P	Viton (G)
CHLORODIBROMOMETHANE		P	P	Viton (G)
CHLOROFORM	2	P	P	Polyvinyl Alcohol (G)
CHLORONAPTHALENES	1	P	P	Viton (G)
CHROMIC ACID	3	F	P	(G)
CISPLATIN		G	G	
CITRIC ACID, 30-70%		E	E	
CYCLOHEXANE	1	E	P	
CYCLOHEXANOL	1	E	G	
CYCLOHEXANONE	1	P	P	Butyl (G)
CYCLOHEXYLAMINE	3	P	P	
DI-N-AMYLAMINE	3	E	P	
DI-N-BUTYLAMINE	3	E	P	
DI-N-BUTYLPHTHALATE	0	E	F	
DI-N-OCTYLPHTHALATE	0	E	F	
DIACETONE ALCOHOL	1	G	F	
DIALLYLAMINE		P	P	Viton (G)
DICHLOROACETYL CHLORIDE	3	P	P	Viton (G)
DIESEL FUEL	0	E	P	
DIETHANOLAMINE	1	E	E	
DIETHYLAMINE	3	G	F	
DIETHYLENE GLYCOL	1	E	E	
DIETHYLENETRIAMINE	3	P	P	Neoprene (G)
DIISOBUTYL KETONE	1	G	P	
DIISOBUTYLAMINE	3	E	P	
DIMETHYL ETHER		G	P	
DIMETHYL SULFOXIDE (DMSO)	1	G	E	
DIMETHYLACETAMIDE	2	F	G	
DIMETHYLFORMAMIDE (DMF)	1	P	P	Butyl (G)

1, 3-DIOXANE		P	F	Butyl (G)
1, 4-DIOXANE	2	P	P	Butyl (G)
EPICHLOROHYDRIN	3	P	F	Butyl (G)
ETHANOL	0	G	G	
ETHYL ACETATE	1	P	F	Butyl (G)
ETHYL ETHER	1	G	P	
ETHYLENE GLYCOL DIMETHYL ETHER	2	F	F	Butyl (G)
ETHYLENE DICHLORIDE	2	P	P	Polyvinyl Alcohol (E)
ETHYLENE GLYCOL	1	E	E	
FORMALDEHYDE, 30-70%	3	E	G	
FORMIC ACID	3	G	E	
FREON 113 OR TF		E	P	
FREON TMC		F	F	Polyvinyl Alcohol (E)
FURFURAL	3	P	P	Butyl (G)
GASOLINE, 40-50% AROMATICS	1	E	P	
GASOLINE, UNLEADED	1	G	P	
GLUTARALDEHYDE, <5%		G	G	
GLYCEROL		E	E	
HEPTANES	1	E	P	
HEXANE	1	E	P	
HYDRAZINE	3	E	F	
HYDROCHLORIC ACID, <30%	3	G	E	
HYDROCHLORIC ACID, 30-70%		G	G	
HYDROFLUORIC ACID,<10%	4	G	G	
ISOBUTYL ALCOHOL	1	E	P	
ISOOCTANE	0	E	P	
ISOPROPYL ALCOHOL	1	E	E	
ISOPROPYLAMINE	3	P	P	Teflon (G)
JET FUEL <30% AROMATICS 73-248C	1	G	P	
KEROSENE		E	P	
LACTIC ACID		E	E	
LAURIC ACID		E	E	
MALATHION,30-70%		G		
MALEIC ACID		G	G	
METHANOL	1	F	F	Neoprene (G)
METHYL ACETATE	1	P	P	Butyl (G)
METHYL ETHYL KETONE	1	P	P	Butyl (E)
METHYL ISOBUTYL KETONE	2	P	P	Butyl (G)
METHYL METHACRYLATE	2	P	P	Polyvinyl Alcohol (E)
METHYLENE CHLORIDE	2	P	P	Polyvinyl Alcohol (G)
AMYL ACETATE	1	F	P	Butyl (G)
BUTYL ACETATE	1	F	P	Butyl (G)
BUTYL ALCOHOL	1	E	E	
N-METHYL-2-PYRROLIDONE	2	P	E	
N-NITROSODIETHYLAMINE		P		Butyl (G)
PROPYL ALCOHOL		E	E	
NAPHTHA, 15-20% AROMATICS		E	P	
NAPHTHA , <3% AROMATICS	1	E	P	
NITRIC ACID, <30%	3	G	G	
NITRIC ACID, 30-70%	3	P	P	Neoprene (G)
NITROBENZENE	3	F	F	Butyl (G)
NITROETHANE	1	P	G	
1-NITROPROPANE	1	P	F	Butyl (G)
2-NITROPROPANE	1	P	P	Butyl (G)
OCTANE	0	G	P	
OCTYL ALCOHOL	1	E	E	
OLEIC ACID	0	E	G	
OXALIC ACID	3	E	E	
PALMITIC ACID		G	F	
PCB (POLYCHLORINATED BIPHENYLS)	2	G	P	

PENTACHLOROPHENOL	3	G	P	
PENTANE	1	E	P	
PERCHLORIC ACID, 30-70%	3	F	F	Neoprene (F)
PERCHLOROETHYLENE	2	G	P	
PEROXYACETIC ACID		P	P	Butyl (G)
PETROLEUM ETHERS, 80-110C	1	G	P	
PHENOL	4	F	F	(F)
PHOSPHORIC ACID	3	G	F	
PICRIC ACID	3	E	G	
POTASSIUM HYDROXIDE	3	E	G	
POTASSIUM IODIDE		G	G	
PROPYL ACETATE	1	F	P	Butyl (F)
PYRIDINE	3	P	P	Butyl (G)
SODIUM CARBONATE		E	E	
SODIUM CHLORIDE		E	E	
SODIUM FLUORIDE	3	G	G	
SODIUM HYDROXIDE,30-70%	3	G	E	
SODIUM HYPOCHLORITE		E	E	
SODIUM THIOSULFATE		G	G	
STYRENE	2	P	P	Polyvinyl Alcohol (G)
SULFURIC ACID, <70%	3	F	G	
SULFURIC ACID, >70%	3	P	P	Butyl (G)
TANNIC ACID	0	G	G	
1,1,1,2-TETRACHLOROETHANE		F	P	Viton (G)
TETRAHYDROFURAN	2	F	P	Teflon (G)
TOLUENE	2	F	P	Viton (G)
TOLUENE-2,4-DIISOCYANATE (TDI)	3	P	P	Butyl (G)
1,2,4-TRICHLOROBENZENE	2	F	P	Teflon (G)
1,1,1-TRICHLOROETHANE	2	P	P	Viton (G)
1,1,2-TRICHLOROETHANE	2	P	P	Viton (G)
TRICHLOROETHYLENE	2	P	P	Viton (G)
TRICRESYL PHOSPHATE	2	G	G	
TRIETHANOLAMINE	2	E	E	
TURPENTINE	1	E	P	
XYLENES	2	F	P	Viton (G)

The National Fire Protection Association (NFPA) has developed a system for indicating the health hazards of chemicals:

4	**Danger, may be fatal on short exposure. Specialized protective equipment required.**
3	**Warning, corrosive or toxic.**
2	**Warning, may be harmful if inhaled or absorbed.**
1	**Caution, may be irritating.**
0	**No unusual hazard.**
	No information available. Avoid skin contact or inhalation..

The compatibility of the glove films with each chemical is color coded as follows:

P	**POOR chemical resistance**
F	**FAIR chemical resistance**
G - E	**GOOD to EXCELLENT chemical resistance**

List of Chemicals and Gases Used at the NIST CNST Cleanroom – (Chemical Inventory is listed in NanoFab_Cleanroom_Chemical_Inventory.doc file.)

The dangers of each chemical is summarized in the table below following the NFPA Hazard Classification, and can be found in the MSDS books located in the main entrance of the Cleanroom.

Flammables	H	F	R	C	Acids	H	F	R	C	Oxidizers	H	F	R	C	Caustic	H	F	R	C	Gases	H	F	R	C
2-Propanol	2	3	2	3	Acetic	3	2	2	4	Ammonium Peroxidisulfate	2	1	1	3	25% Tetramethyl-ammonium Hydroxide	3	1	1	4	Helium	0	0	0	0
Acetone	1	4	2	1	Silicic	2	0	0	1	Hydrogen Peroxide	3	0	3	4	Potassium Hydroxide	3	0	2	4	Forming Gas N2/H2	0	2	0	0
Ethyl Alcohol	3	3	0	0	Sulfuric:	2	0	1	3	Xenon Difluoride	1	0	1	3	Ammonium Hydroxide	3	0	1	4	Oxygen	0	0	0	0
Hexamethyldisilazane	2	4	2	0	PAE Etchant (Phosphoric Acid Etch)	3	0	2	3						MF-321 e-Beam Resist Remover	4	0	2	4	Hydrogen	0	4	0	0
Methanol	3	3	1	3	Buffered Oxide Etch	4	0	2	4						Microposit 351 Developer	4	0	2	4	Nitrous Oxide	1	0	0	0
Methyl Alcohol	3	3	1	3	CR 9 Chromium Etchant	2	2	2	3											Trifluoromethane	1	0	0	0
Microposit 1165 Remover	2	3	1	1	CR 7 Chromium Etchant	2	2	2	3											Silane	2	4	3	0
RS 100 Photoresist Stripper	2	3	0	0	Hydrochloric	3	0	2	4											Oxygen	3	0	0	0
Tetramethylammonium Hydroxide 25% (TMAH)	3	1	1	4	Hydrofluoric	3	0	2	4											Nitrogen	1	0	0	0
Xylene	2	4	1	0	Nitric	4	0	3	4											Ammonia	3	1	0	3
					Phosphoric	3	0	2	4											Argon	0	0	0	0
																				Dichlorosilane	4	4	2	3
																				5% Silane/Helium	2	4	3	0
																				Sulfur Hexafluoride	1	0	0	0
																				Chlorine	4	0	0	3
																				Boron Trichloride	3	0	2	3
																				Octafluoro-cyclobutane	1	0	0	0
																				Carbon Tetrafluoride:	1	0	0	0

Table 2- Cleanroom Chemicals and NFPA Hazard classification: Health, Flammability, Reactivity, Contact

NFPA Hazard Classification	Health	Flammability	Reactivity	Contact
4	Deadly	Flash Point < 73° F	Explosive at room Temperature	Extremely damaging
3	Extreme Danger	Flash Point < 100° F	Shock and heat may detonate	Severe damage
2	Hazardous	Flash Point > 100° F < 200° F	Violent Reaction with water	moderate damage
1	Slightly Hazardous	Flash Point > 200° F	Unstable if heated, not violent	Slight damage
0	Normal Material	Will not burn	not reactive with water	Low or no danger

Table 3- National Fire Protection Agency Hazard Classification Chart