Notre Dame Nanofabrication Facility

Laboratory Operations & Safety Procedures Manual

Department of Electrical Engineering
University of Notre Dame

This manual is thought to be complete at the time of its writing and to accurately represent the operational policies of NDNF and the dangers involved in using NDNF facilities. Comments and suggestions regarding the contents of this manual should be directed to:

Mark Richmond at mrichmon@nd.edu

Rev. 14, August 18, 2021

Edited and approved by the Nanofabrication Laboratory Oversight Committee

Patrick J. Fay, Director (574-631-5693)
Gary H. Bernstein
Suman Datta
David Go
Douglas C. Hall
Anthony Hoffman
Scott Howard
Lei Liu
Alexei Orlov
Wolfgang Porod
Alan C. Seabaugh
Gregory L. Snider
Greg Timp
Pinar Zorlutuna

Mark Richmond, Lab Manager (574-631-6478)

A basic policy of the University of Notre Dame is to provide a safe working environment for its students and employees. A commitment to safety is especially important in university laboratories where many potential safety hazards exist. To achieve effective laboratory safety, the following guidelines and policies in this manual have been established.

NDNF Safety Policy: The Staff and Management of the NDNF 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 facility. Adherence to these safety recommendations will reduce laboratory accidents, spills and fires.

Users violating the operating and safety rules of the facility or endangering the safety of themselves or other users will be denied further access to the laboratory at the sole discretion of the management.

Table of Contents

IMPORTANT TELEPHONE NUMBERS

EMERGENCY..... 911 (wired phone)
631-5555 (cell phone)

Campus Security (Police) 1- 5555
This number is open 24 hours.

Risk Management and Safety Office 1-5037

8:00 AM to 5:00 PM
- Chemical Waste Pickup
- Chemical Spill Response
- Chemical Safety Information

Memorial Hospital 647-1000

St. Joseph Medical Center 237-7264

Poison Control Center..... 1-800-222-1222

University Health Services..... 631-7497/631-7567

Introduction to the Notre Dame Nanofabrication Laboratory

Welcome to the Notre Dame Nanofabrication Laboratory. This first-rate teaching and research cleanroom facility houses a wide array of tools for material and device processing that have been provided to enable a wide range of research projects and topics. Admittance to this facility is a privilege and not a right. Safety is the most important aspect of using the lab! You, as a user, must do everything possible to ensure your own safety as well as that of those around you. In addition, in order to preserve the cleanliness of the lab and the processing equipment, a number of operational protocols have also been established to ensure that the facility serves all users well. This manual will provide the basic safety rules and guidelines, as well as the required operational protocols, to ensure that your work is as productive and safe as possible.

Safety is an overriding concern in all NDNF laboratory activities. All operations must be undertaken with the safety of both the individual user and other users as the primary consideration. In fact, operating safely is more important than getting your project done. As a general rule, anyone who violates any safety rule or otherwise compromises his or her personal safety or the safety of others will be denied access to the laboratory. These suspensions will be determined by the lab director and may include permanent suspension. Ignorance of the rules, fatigue, language difficulties, carelessness, and haste are not acceptable excuses for unsafe behavior. For graduate students, violations could mean the end of your dissertation research. For outside users, it could mean the end of your use of the facility. As a general rule, minor infractions will typically result in a warning and requirement for re-training in the appropriate protocols. Major infractions, or repeated minor infractions, will result in immediate suspension of laboratory privileges. Readmission to the laboratory will be at the sole discretion of the laboratory management.

We wish to keep the laboratory an informal and friendly place to work. The staff wishes neither to make nor enforce rules unnecessarily. For the most part, rules on chemical use are formulated on the basis of basic chemical knowledge, the properties of individual chemicals, and common sense. Likewise, the various protocols for compressed gas handling, vacuum equipment use, etc, are informed by basic operational principles. Laboratory contamination control protocols – including gowning requirements, selection of personal protective equipment, and limits on materials permitted in various systems and areas of the lab – have also been formulated to provide a safe and productive work environment for research. In many cases, rules have been created in response to specific incidents or common misunderstandings. In addition, a large volume of state and federal law covers various aspects of facility operation and disposal of waste. In spite of rules and staff supervision, primary responsibility for safety and proper adherence to protocol rests with the individual user. A responsible, considerate user with an understanding of basic principles and common sense will have little trouble with our safety rules or protocols.

A majority of problems, safety and protocol violations, and equipment damage in the laboratory are the result of haste and failure to follow established procedures and apply common sense. While it is certainly true that lab users are under pressure to produce results, taking short-cuts or attempting to work too quickly often results in wasted samples, wasted time and money,

and poor results. It can also lead to users breaking equipment or fixtures, and personal injuries. Carelessness or hasty behavior in the lab simply will not be tolerated.

Your safety in the laboratory is determined not only by your actions but also by the actions of those around you. Since the staff is in the laboratory only a fraction of the time the facility is open, the users are often in the best position to observe the behavior of others. Thus, if you observe someone else in the lab working in an unsafe or inappropriate manner, it is your responsibility to first bring it to his or her attention, and then if necessary, bring it to the attention of the laboratory manager or laboratory director. The access of everyone to the facility depends on maintaining a safe working environment. A series of thoughtless violations or a single serious personal injury could result in closing of the laboratory for weeks. We hope that peer pressure will result in conformance to safety standards where direct staff observation is not possible.

Potential dangers exist in many forms. For example, the laboratory is filled with sophisticated equipment employing chemicals that are dangerous on several levels either by themselves or in combinations. Also, compressed gases and high voltages are used in nearly every system, and the potential for electrical shock, cryogenic burns, and other hazards are also present. This operations and safety manual is intended to provide guidance to users for safe and productive operation in the lab. Additional instruction and guidance is available from the lab staff to address questions or uncertainties.

Overview of Laboratory

The figure on pages 9-10 shows a layout of the cleanroom laboratory, with the location of major pieces of equipment shown. As can be seen, the lab consists of three large areas (indicated by their cleanliness level). The class 10,000 area (shown shaded in blue) houses CMP, wafer thinning, and crystal growth facilities. The class 1000 and 100 areas (shaded in green and tan, respectively) house the rest of the processing capabilities, including metal deposition, lithography, oxidation, dielectric deposition, plasma processing, and wet-chemical processing. In order to preserve the cleanliness of the environment, strict gowning and operational procedures have been adopted, and all users must adhere rigorously to these procedures. These procedures are described in detail in subsequent sections of this manual. In addition to the cleanroom spaces, this safety manual also applies to the NDNF-associated labs in B06 and 132 Stinson-Remick (wirebonding, dicing saw rooms). It is critical to note that, due to the complexity and sensitivity of many of the tools in the lab, a strict training regimen is in place. All users must be trained by a member of the laboratory staff prior to using any equipment in the lab. To arrange training for a specific tool, users should contact the lab manager (Mark Richmond). Users desiring advice on process design or selection of tooling to accomplish their research goals should contact the lab director (Patrick Fay) or other faculty affiliated with the facility.

Hours of Operation

The laboratory is in operation 24 hours a day, 7 days a week. It is open only to qualified users who possess a keycard to access the laboratory. New users may be restricted from 8 to 5 Monday through Friday.

Badges and Keycard Access

The keycard is your authorization to enter the facility. The keycard is essentially your proof that you have received the required orientation and safety training. Keycards are issued for the sole use of a single person. Loaning your keycard to anyone else is strictly forbidden. Sharing of keycards or permitting unauthorized access to the facility is prohibited. The initial keycard issued is at no charge to you. However, if you break or lose your electronic keycard, there will be a $10 keycard replacement fee. Non-resident users will receive keycards for temporary use, and must be returned at the end of each visit. Persons without keycards specifically issued to them are not allowed to work in the facility. The badges are property of the University and must be returned when no longer needed.

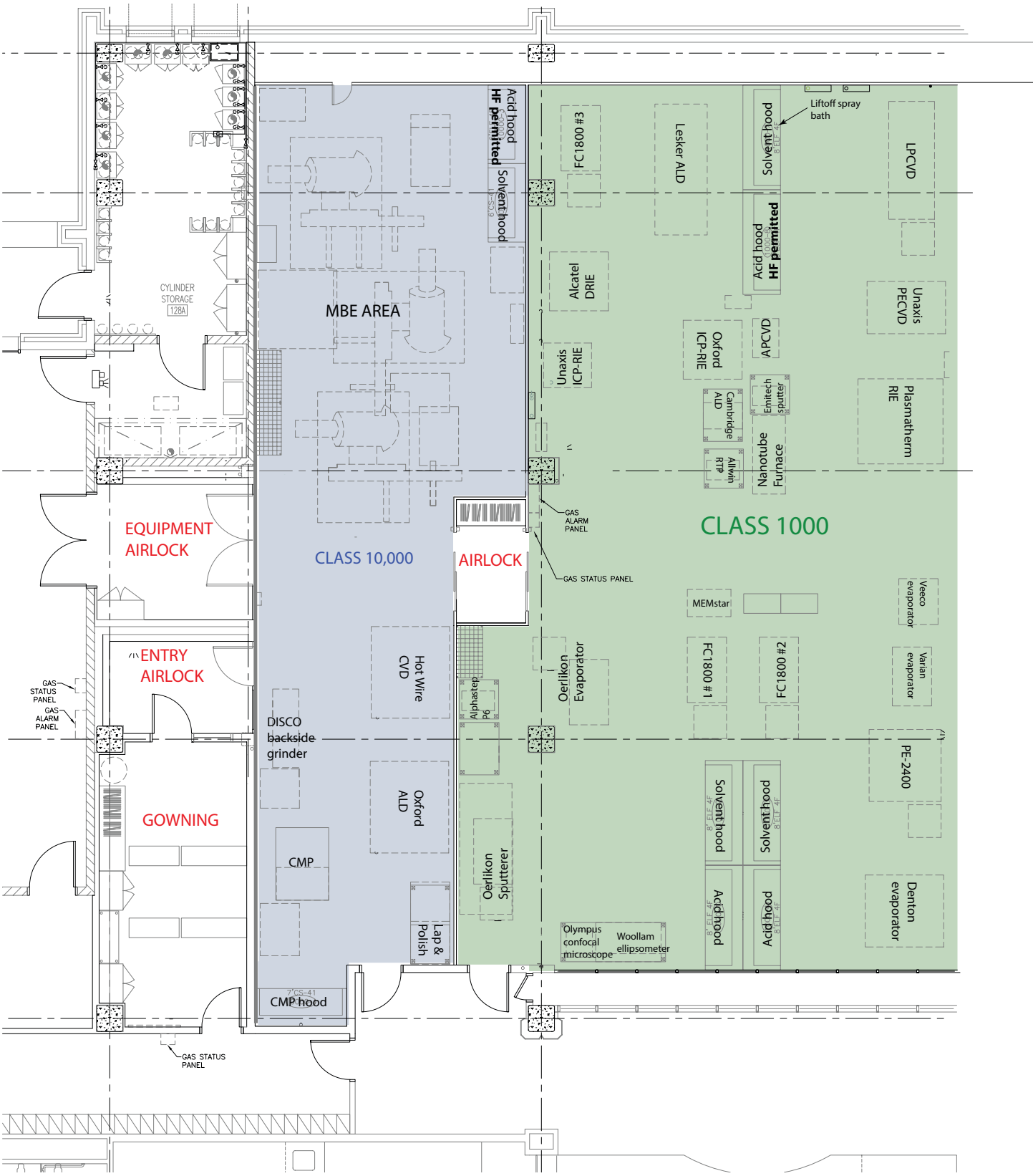
Key Card Access ID Badges

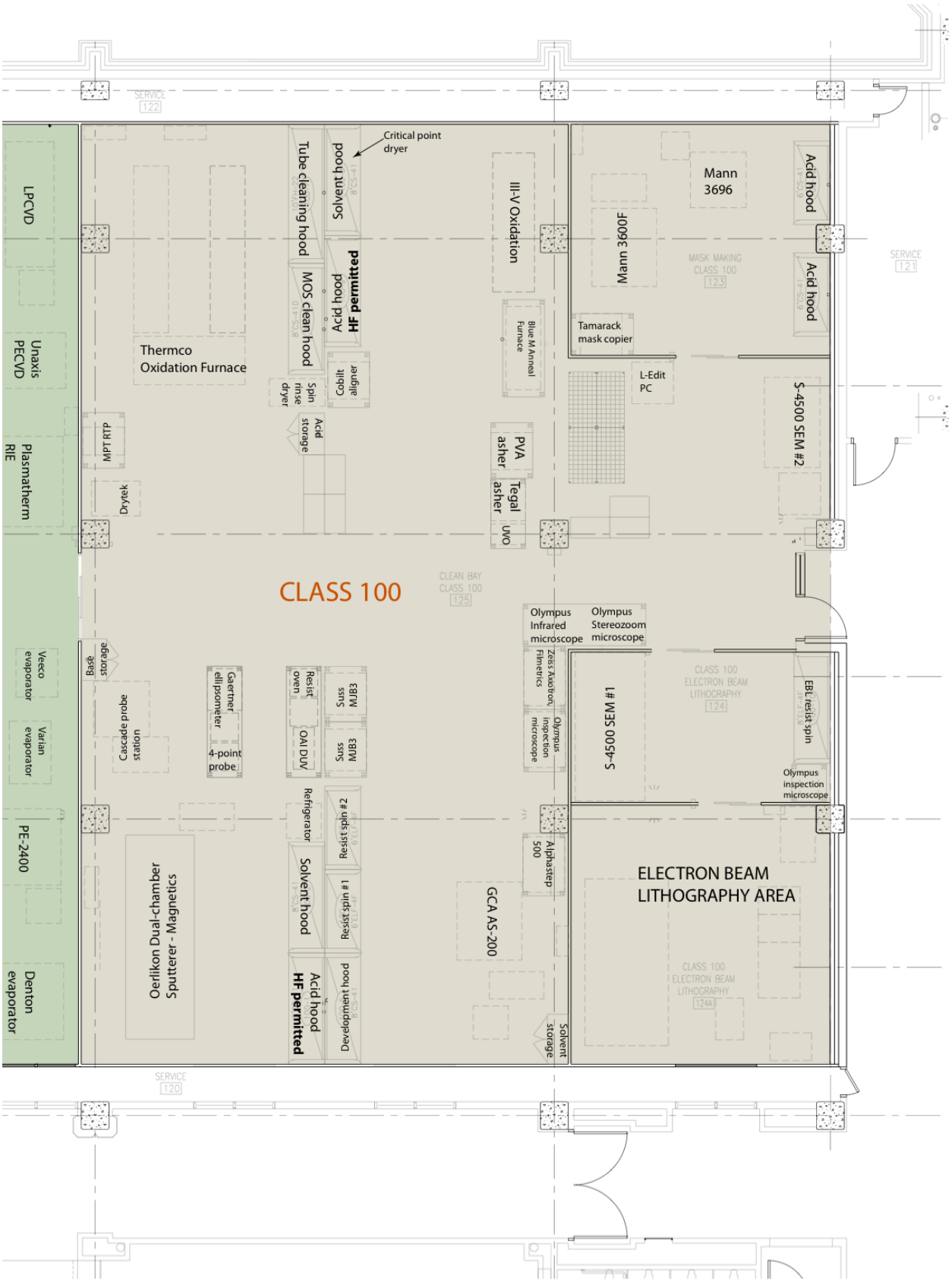
a) Will have your picture, name, advisor's name, and an RF ID tag. The badge must be worn at all times while inside the lab.
b) All users are responsible for the security and safety of their own badge.
c) Do not use anyone else's badge or allow your badge to be used by others.
d) Entry and exit to the lab will be through the gowning room using the keycard for normal routine use.
e) Access ID badges are the property of the University and must be returned (to the Laboratory Manager) when no longer needed.

Visitors

No one may enter the facility without approval from laboratory management. Consequently, all guests or visitors must be approved for entry into the cleanroom by lab management --in general, users may <u>not</u> bring friends, family, colleagues or others into the laboratory without the express permission of lab management. Any person escorting guests or visitors into the laboratory is directly responsible for their actions and their safety when touring the facility. The escort must be a registered user of the lab and have signed the lab "Safety Manual Agreement". A "guest" or "visitor" is anyone without a permanent keycard specifically issued to him or her. A "guest" is anyone coming into the lab for a tour or as a courtesy to show them our lab. These people will be issued temporary "guest" badges that have no RFID tag on the badge and as such do not have to log in or out of the lab. A "visitor" is someone who has access to the lab and will be issued a temporary "Visitor" badge with an RFID tag and as such must log in and out of the lab. A visitor badge will be issued for a period up to about 30 days. For longer periods the person will be issued a picture ID badge for entrance into the lab. Visitors using the lab must sign the lab "Safety Manual Agreement".

Group tours are a considerable disruption of the facility operation. Please make every effort to schedule them in advance with the Laboratory Manager.


CYLINDER STORAGE 128A
EQUIPMENT AIRLOCK
ENTRY AIRLOCK
GOWNING
GAS STATUS PANEL
GAS ALARM PANEL
MBE AREA
CLASS 10,000
AIRLOCK
DISCO backside grinder
CMP
CMP hood
Hot Wire CVD
Oxford ALD
Lap & Polish
Alphastep P6
Oerlikon Sputterer
Acid hood HF permitted
Solvent hood
Alcatel DRIE
Unaxis ICP-RIE
FC1800 #3
Lesker ALD
Oerlikon Evaporator
Liftoff spray bath
Oxford ICP-RIE
Cambridge ALD
Allwin RTP
Emitech sputter
Nanotube Furnace
APCVD
LPCVD
Unaxis PECVD
Plasmatherm RIE
CLASS 1000
MEMstar
FC1800 #1
FC1800 #2
Veeco evaporator
Varian evaporator
PE-2400
Denton evaporator
Olympus confocal microscope
Woollam ellipsometer


SERVICE 122
LPCVD
Unaxis PECVD
Plasmatherm RIE
Veeco evaporator
Varian evaporator
PE-2400
Denton evaporator
Tube cleaning hood
Solvent hood
Critical point dryer
Acid hood
HF permitted
MOS clean hood
Spin rinse dryer
Cobilt aligner
Acid storage
Thermco Oxidation Furnace
MPT RTP
Drytek
III-V Oxidation
Blue M Anneal Furnace
PVA asher
Tegal asher
UVO
Mann 3696
Mann 3600F
Tamarack mask copier
L-Edit PC
MASK MAKING CLASS 100 123
Acid hood
Acid hood
S-4500 SEM #2
SERVICE 121
CLASS 100
CLEAN BAY CLASS 100 125
Olympus Infrared microscope
Olympus Stereozoom microscope
Zeiss Axiotron, Filmetrics
Olympus inspection microscope
S-4500 SEM #1
CLASS 100 ELECTRON BEAM LITHOGRAPHY 124
EBL resist spin
Olympus inspection microscope
Bag storage
Cascade probe station
Gaertner ellipsometer
4-point probe
Resist oven
OAI DUV
Suss MJB3
Suss MJB3
Refrigerator
Resist spin #2
Solvent hood
Resist spin #1
Acid hood
HF permitted
Development hood
Oerlikon Dual-chamber Sputterer - Magnetics
GCA AS-200
Alphastep 500
Solvent storage
ELECTRON BEAM LITHOGRAPHY AREA
CLASS 100 ELECTRON BEAM LITHOGRAPHY 124A
SERVICE 120

1.0 GENERAL LABORATORY PROCEDURES

There are many users of the laboratory. Common courtesy, common sense, respect for others, knowledge of the hazards, and cleanliness are all essential parts of laboratory operation.

1.1 BEHAVIOR IN THE LABORATORY

1. Laboratory users shall act in a professional manner at all times.
2. Horseplay and practical jokes are expressly forbidden.
3. Never work alone at a potentially dangerous activity.
4. Visitors to the laboratory must observe all safety regulations, including, but not limited to the wearing of proper cleanroom garments and eye protection.
5. Laboratory users shall be aware of the location and proper operation of laboratory safety equipment.
6. All users must adhere to cleanliness protocols at all times. Pencils, paper, cardboard, and other particulate-generating materials are expressly forbidden. Lab attire must not be opened or removed except in the event of a chemical spill or emergency.
7. Any chemicals in a hood must be labeled (directly on the container, beaker, etc. or clearly indicated on a cleanroom wipe the container is sitting on). The user's full name and current date must be clearly printed on a clean room wipe in the work space within the hood.
8. Use of mercury-based thermometers in the laboratory is not permitted at any time. Glass thermometers are discouraged; use of thermocouple or electronic temperature sensors is preferred.
9. Users must not use other users' tools, glassware, etc, without permission. Unauthorized use of others' equipment is grounds for revocation of lab privileges.

1.2 CLEANROOM GOWNING PROTOCOL AND PERSONAL PROTECTIVE EQUIPMENT

All users entering the cleanroom are required to wear proper cleanroom garments. These garments are provided for your use in the gowning room (room 129). Note that the gowning requirements depend on the area of the cleanroom to be entered, and additional protective equipment beyond this minimum level of protection is required for some operations. In addition, the sequence and technique for donning the cleanroom garments are critical to maintaining a clean lab environment, and so special care to strictly adhere to this protocol is absolutely essential. No deviations are permitted.

The gowning requirements for the lab are as follows:

Class 10,000 area: This is the first room after exiting the airlock from the gowning area (light blue on diagram on page 9). The minimum gowning required for this area is a cleanroom lab coat (as of this writing, these are blue in color), a hairnet, disposable booties, gloves, and safety glasses. Shorts or other clothing that result in exposed skin are unacceptable for use under a cleanroom lab coat. Open-toe shoes (e.g. sandals, flip-flops) are not acceptable footwear in the cleanroom. If you will need to work in both the class 10,000 and the 1000 or 100 areas, gown up per the class 1000/100 protocol below. Beard covers are available and optional. Note: when wearing a hair net, **all** of your hair must be under the hair net. **WARNING:**

Anyone in a lab coat **ABSOLUTELY WILL NOT** enter the Class 1,000 or Class 100 areas wearing a lab coat. If you do, you will lose access privileges to the cleanroom, period! The class 10,000 & 1000/100 areas are separated by a double set of doors, this is an airlock for isolation.

Class 1,000 and 100 areas: This is the second and third rooms (past the airlock—colored green and tan in the diagram on pages 9-10) and includes rooms with the orange-filtered lights. Users entering this area must be fully gowned up. The proper attire for these areas is a hairnet, disposable booties, a hood, a set of coveralls, a pair of full-height booties, gloves, and safety glasses. Open-toe shoes (e.g. sandals, flip-flops) are not acceptable footwear in the cleanroom. Beard covers are available and optional.

Below is the procedure for gowning for cleanroom access:

1. Put on hair net. All hair must be contained within the hair net (beard covers are also available, but are optional)
2. Short booties (blue booties/shoe covers are disposable, white booties are reusable–wipe down when returned). To put these on, sit down at the first bench, put one shoe cover on and move your foot to the other side of the bench, put the other shoe cover on and move your foot over to the other side of the bench
3. Put on gloves
4. Put on hood (not required for Class 10,000 areas)
5. Put on coveralls (Class 1000 & 100 areas) or a blue lab coat (Class 10,000 only). Be sure to tuck the hood inside coveralls
6. Put on full-height booties, fastening the snaps at the top as necessary (Class 1000 & 100 areas). To do this, sit down at the second bench, put one bootie on and move your foot to the other side of the bench, then put the other bootie on and step on the clean side of the bench
7. Put on safety glasses or goggles
8. Look in the mirror to make sure you are correctly dressed and covered to enter the cleanroom

Just as users must be properly gowned to preserve the cleanliness of the lab, all items that users bring into the lab must also be compatible with cleanroom operation. Materials that generate particles are forbidden; this includes pencils, paper (including magazines, technical papers, and books), cardboard, packing material, leather or cloth tablet or phone cases or straps, etc. This list is not comprehensive, so if you are uncertain, ask. Any item brought into the cleanroom must be wiped down with a 70% alcohol/30% water solution. Wipes and this solution are available in the gowning area. This wiping protocol applies to all items being brought into the lab, including new glassware, tools, sample boxes, chemical bottles, etc. The only type of notebook that is allowed into the cleanroom is a cleanroom-compatible version available from the lab staff (available at cost from Mark Richmond or other lab staff). Lab notes, reference material, or any manuals to be brought in must be printed on cleanroom compatible paper (also available at cost from the lab staff). Note that due to this wipe-down requirement for all items entering the cleanroom, users are encouraged to minimize the number of items brought in and out of the lab. The use of pencils is not permitted as they generate particulates; only ball-point pens and markers are allowed.

While in the cleanroom, you may not open your coveralls for any reason (e.g. to retrieve phones, flash drives, pens, or to check your watch). If you are bringing in a flash drive, phone, pens or any other item, these must be wiped down in the gowning room as outlined above, and cannot be in your pocket (since you won't be able to get to it).

In order to preserve the cleanliness of the reusable garments, the correct protocol for ungowning must also be followed. The procedure is:

1. Remove full-height booties. This should be the reverse process of putting them on—sit at the first bench, remove them one at a time, swinging your leg over the bench and standing up in the middle section of the gown room only when both booties have been removed. Place booties in the yellow bins according to size; place the booties sole-to-sole and wrap them together as a pair before placing in the bin.
2. Remove coveralls and hang up on the hangers for reuse. Please snap the garments at the top so that they do not fall off the hanger. Note: if a garment has been soiled or begun to smell, please place in the laundry hamper below the exit RFID reader for laundering.
3. Remove hood (hang up on the same hanger as the coveralls)
4. Step over the second set of benches (to the "dirty" side of the room), and remove booties, gloves, hair net & beard cover, and discard in the **gray** trash can.

There are numerous hazards in the laboratory. Each user is responsible for and required to use and know the types of protective equipment available. Everyone entering the laboratory must wear the appropriate eye protection, gloves, and cleanroom garments as a minimum of protection while inside.

1.3 AVOIDANCE OF ROUTINE CHEMICAL EXPOSURE

1. Always avoid skin contact with chemicals.
2. Do not smell or taste chemicals.
3. Never pipette by mouth. Use a vacuum or a pipette bulb.
4. Apparatus which may discharge chemical vapors or dust that might produce adverse toxic effect must be vented into local exhaust devices.
5. Chemical reactions involving two or more substances may form reaction products that are significantly more toxic than the starting reactants. Always assume that all substances of unknown toxicity are toxic.
6. Always use common sense, good judgment, professional expertise and safety awareness when it comes to hazardous chemicals.

1.4 PERSONAL HABITS IN THE LABORATORY

1. Eating, drinking, chewing gum and wearing or applying cosmetics or other aromatic products on exposed skin is not permitted in the laboratory.
2. Smoking is not allowed in the laboratory.
3. Confine all hair inside the hair net and/or hood.
4. Be sure cleanroom garments are worn properly, correctly fitted, and are clean and undamaged. This includes ensuring that all hair is confined inside the hair net.
5. Wash hands upon exiting the laboratory area, particularly before using the restroom, eating, drinking, or smoking.
6. Sleeping is not permitted in the lab.

1.5 UNATTENDED OPERATIONS

1. Unattended wet chemistry operations are not permitted in the cleanroom. This means that you may not leave chemicals out in a hood when you are not physically present in the laboratory. If you must leave the lab for any reason, either discard the chemicals before leaving, or ask another user to take responsibility for the chemicals in your absence.
2. Long processes such as slow lift-offs that require long soak times must be performed in a closed container. These containers are to be labeled (chemical name, user name), and must be **stored** in an appropriate chemical storage cabinet. They may not be left in the hood. For processes requiring long run times other than lift-off, consult with lab staff so that an appropriate protocol can be developed.
3. Laboratory lights should be left on when users are present.

1.6 HOUSEKEEPING

There is a limited amount of storage space inside the laboratory. Each user is issued one (1) plastic bin for storage of glassware and samples, but these storage bins are not for storage of chemicals. A smaller number of lockers (outside the cleanroom) and cabinets (inside the cleanroom) are available. The lockers outside the cleanroom are only for temporary storage, and are shared among a large number of users. The storage cabinets inside the cleanroom should be used for keeping only currently needed samples, masks, etc., and the allocation and assignment of these in-lab storage areas is at the discretion of the lab management. Chemicals are to be stored only in the designated chemical cabinets. Items left out or in unassigned areas will be disposed of.

1. Clean up after yourself (dispose of chemicals, wipes, pipettes, etc.)
2. Lab areas (benches, hoods, tables, etc.) will be kept clean and uncluttered.
3. No glassware may be left out when not in use. Glassware left unattended will be confiscated.
4. Any spills or accumulations of chemicals on work surfaces shall be removed as soon as possible with techniques that minimize residual surface contamination.
5. Floors and walkways should be kept dry at all times.
6. Doorways and walkways shall not be blocked or used for storage.
7. Access to exits, emergency equipment, and utility controls shall never be blocked.
8. For those that do not follow the rules, there are penalties. Your samples, glassware, etc, may be confiscated by the lab staff, and future lab privileges may be curtailed for habitual offenders.

1.7 GLASSWARE

Glassware is used throughout the laboratory. The use of glass thermometers is strongly discouraged in the laboratory. Use electronic temperature monitoring devices (e.g. thermocouples, resistive thermal devices) instead. The use of mercury-based thermometers is strictly forbidden in the laboratory at all times. For general lab glassware, care should be taken in handling and use. Before use, the glassware should be inspected for any defects and cracks. Quick dump rinse tanks ("QDRs") are not to be used to clean glassware. Several pieces of the glassware in the laboratory have ground joints. These joints should never be put on tightly, especially at temperature extremes, because this can cause them to get stuck. All broken glassware (beakers, pipettes, silicon wafers, etc.) should be disposed of in the

plastic bin in the Class 100 area labeled "Broken Glass". Broken III-V wafers and III-V materials to be discarded should be placed in the "III-V waste" bin in the Class 100 area near the broken glass bin.

1.8 WORKING WITH VACUUM

In a vacuum system, the higher pressure is on the outside, rather than on the inside, so a break can cause an implosion rather than an explosion. The resulting hazards consist of flying glass and damage from this debris. Special precautions including eye protection are required. Glass bell jars at reduced pressure are capable of collapsing violently either spontaneously (if cracked or weakened in some other way) or from an accidental blow. Adequate shielding must be in place. It is advisable to check the bell jar at each use.

1.9 OVERVIEW/RECAP – GENERAL LAB PROCEDURES

A summary of the policies related to general use of the lab is:

For all Emergencies – dial 911 from a wired phone, 631-5555 from a cell phone

- **No unauthorized access**
- **No loaning of keys or keycards**
- **No unauthorized chemicals**
- **No unauthorized solutions**
- **No unlabeled solutions**
- **No food or drinks**
- **No chemicals in wastebaskets or down the drain**
- **No unwashed bottles in waste baskets**
- **No unauthorized use of equipment**
- **No pencils, paper, cardboard, or packing materials**
- **Be neat, Be clean, Be Safe**
- **Be courteous and clean up**
- **Wear proper cleanroom garments and protective gear**
- **Read Safety Data Sheets**
- **Know emergency procedures**
- **Read the signs, instructions and notices**
- **Ask if you have questions or don't understand**
- **Think before you act**
- **Notify lab staff immediately of equipment failures or problems**
- **Report violations of lab safety rules to the lab director or manager**

You can lose access to the laboratory if you violate any of the laboratory policies, safety rules, or cause injury to personnel or damage equipment.

2.0 CHEMICALS

All users of the laboratory should know as much as possible about the chemicals being handled and used for processing. Read the container label, safety data sheets (SDS), literature in the library and or consult with your supervisor, PI or the Chemical Hygiene Officer at the Risk Management and Safety Office.

Prior to bringing any new chemical into the lab, the user must have the SDS, be aware of the storage requirements and have a place to store it, know the proper handling procedures, have a disposal procedure for the chemical, have any necessary PPE (Personal Protective Equipment), and inform the lab director so that this information can be evaluated and reviewed for proper safety procedures.

The SDS list for all the chemicals in the lab can be accessed online at https://riskmanagement.nd.edu (look under "quick links" and scroll to "Safety Data Sheets" and then "Notre Dame MSDS Online Lookup.")

No chemicals are to be stored in your lab bin! These bins are for glassware and sample storage. If you buy a new chemical and bring it into the lab, you are responsible for getting the SDS sheet and submitting a copy of it to the Laboratory Manager. The chemical inventory and Safety Data Sheets are maintained by the Laboratory Manager for all chemicals used in the laboratory. Chemicals that are specially ordered for you/your project/your professor should be labeled as such with your name, date, and professor or person responsible for it.

Chemical guidelines for use inside the laboratory on the benches and hoods:

1. *One* cleanroom wipe with your full name and date clearly printed must be under all containers with chemicals in them.
2. All chemical containers must be clearly labeled (on the glassware or the wipe). Use a ballpoint pen so that your writing will be legible. This label must clearly indicate the chemicals present. Do not use abbreviations.
3. All chemical processing must be done in a hood.
4. Chemicals must **never** be transported between hoods in open containers (e.g., beakers).
5. No chemicals will be left overnight without prior approval from the lab management. This permission will generally not be granted unless it is absolutely necessary for a particular process.
6. Under no circumstances may chemicals be left more than 24 hours.
7. No glassware may be left overnight to "air dry".
8. Quick dump rinse tanks ("QDRs") are not to be used to clean glassware.
9. When using a bottle containing a chemical, use all of it before opening a new bottle.

Laboratory users not following the guidelines will face sanctions, which may include having samples and glassware confiscated and solutions discarded by the lab staff. Future laboratory privileges may also be revoked for habitual offenders.

2.1 PROCUREMENT

1. All chemicals used and brought into the Laboratory must have the approval of the Laboratory Director.

2. Prior to purchasing a chemical, the following must be considered:
    a. Proper storage and handling procedures
    b. Are facilities adequate to safely handle the material?
3. An SDS is required for all chemicals brought into the laboratory. This is the responsibility of the person bringing the chemical into the laboratory. When bringing in a potentially new chemical, check the on-line list of lab chemicals at http://www3.nd.edu/~ndnf/facilities/Chemicals_in_the_CR.xlsx or with the Laboratory Manager to see if the SDS is already on file.
4. No chemical will be allowed in the laboratory without an identifying label.
5. When ordering chemicals, do not order more than you expect to need for your project. Excess chemicals that have expired are expensive to dispose of.
6. All chemicals brought into the laboratory must have a date on the chemical container indicating when it was ordered and the person responsible for the chemical. If the container comes with a paper label, this should be covered with clear packing tape to prevent particulates in the cleanroom.
7. If secondary containers are used (e.g. small "frequent-use" bottles filled from larger ones, as is typical for photoresist, etc.), they must adhere to all of the labeling requirements of the primary bottle. This includes:
    a. Chemical name (spelled out, no abbreviations or chemical formulas)
    b. Date
    c. User's name, or PI's name as appropriate
    d. GHS hazard pictograms and/or verbiage

2.2 SECONDARY STORAGE REQUIREMENTS

Laboratory users may find it convenient to prepare small batches of chemical solutions for later use, or to distribute chemicals purchased in large volumes into smaller containers for easier dispensing or handling. This is an acceptable practice, but these secondary storage containers (i.e. containers that are not the original containers from the manufacturer) must be properly labeled. Each secondary storage container must be labeled with the full chemical names (spelled out, no abbreviations or chemical formulas). The label must also include the official GHS pictogram(s) or verbiage for the hazard class(es) of the chemicals (e.g. flammable, toxic, corrosive, etc.). If you are not sure what hazard labels are needed, consult the SDS for the constituent chemicals (note that more than one hazard class may be required). A printer that can print labels, including the GHS pictograms, is available in the equipment airlock. The label must also have your name (or your group's name), date and chemical composition (not just a list of the constituents). Chemicals must be stored in an acid or solvent cabinet.

2.3 CHEMICAL WASTE DISPOSAL

Each user working in the laboratory has a responsibility to see that all chemical wastes they generate are disposed of properly. Prior to using any chemical, a lab user MUST be sure that they understand the proper disposal procedures; starting a process without knowing the proper procedures for disposing of the chemicals and byproducts is a serious violation of lab safety rules. **It is the responsibility of each lab user to know if the chemicals they are using are acids, bases, solvents, etc., and how each is to be disposed of.** Users should be aware that under no circumstances may solvents be flushed down the drain. Additionally, no

solution with a pH < 2 or pH > 12 can be disposed of down the drain. As nearly all acid and base solutions used in common semiconductor processing exceed these limits, the following guidelines will be followed for disposal of chemicals:

1. All solvents must be discarded in one of the solvent waste cupsinks located in the solvent hoods in the cleanroom.
2. Acidic solutions (except those noted below) are to be disposed of in the acid waste cupsinks in the acid hoods in the cleanroom. Users must not carry waste acid solutions outside of the hoods in which they are processing; use the waste disposal cupsink within the acid hood being used.
3. Bases (caustics) except for those noted below are to be discarded in the caustic waste cupsinks in the hoods in the cleanroom. Users must not carry waste base solutions outside of the hoods in which they are processing; use the waste cupsink within the hood being used.
4. **EXCEPTIONS**: There are exceptions to the rules outlined above. These are:

   Acids:

   a) Any solution containing hydrofluoric acid (HF), or acetic acid must be put in a waste container and labeled as such for proper disposal. Note: this includes the tantalum etch Transene SIE-8607, which is a mix of HF and nitric acid. The exception is HF used in the baths in the MOS cleaning and tube cleaning hoods; these hoods have integral HF disposal facilities. Empty waste bottles for HF disposal are stored on the HF waste cart. Bottles for disposal of acetic or other acids are stored in the lower cabinets (beneath the work surface with hinged doors) in the 10000-3, 1000-4, and 100-9 acid hoods. Be sure to thoroughly deface the original label, and clearly mark the bottle with the words "Hazardous Waste" and the name of solution you are disposing. Cap the bottle, and place in the lower cabinet (under the work surface) for storage. If there is not enough room there, place the waste bottle in the back of the hood, and contact lab staff to have the bottle removed.

   b) Copper etchant (e.g. $FeCl_3$ based solutions) must be collected separately for disposal due to environmental regulations. Empty waste bottles for waste disposal are stored in the lower cabinets in the 10000-3, 1000-4, and 100-9 acid hoods. Be sure to thoroughly deface the original label, and clearly mark the bottle with the words "Hazardous Waste" and the name of solution you are disposing. Cap the bottle, and place in the lower cabinet (under the work surface) for storage. If there is not enough room there, place the waste bottle in the back of the hood, and contact lab staff to have the bottle removed.

   Bases:

   c) Any solution containing ammonium sulfide, potassium iodide (gold etch), or EKC 265 stripper must be put in a waste container and labeled for proper disposal; it must not be disposed of in the caustic cupsinks. Empty waste bottles for waste disposal are stored in the lower cabinets in the 10000-3, 1000-4, and 100-9 acid hoods. Be sure to thoroughly deface the original label, and clearly mark the bottle with the words "Hazardous Waste" and the name of solution you are disposing. Cap the bottle, and place in the lower cabinet (under the work surface) for storage. If there is not enough room there, place the waste bottle in the back of the hood, and contact lab staff to have the bottle removed.

Other:

d) All solutions containing iodine complexes (e.g. gold etchant) must be collected separately, regardless of pH. Empty waste bottles for waste disposal are stored in the lower cabinets in the 10000-3, 1000-4, and 100-9 acid hoods. Be sure to thoroughly deface the original label, and clearly mark the bottle with the words "Hazardous Waste" and the name of solution you are disposing. Cap the bottle, and place in the lower cabinet for storage. If there is not enough room there, place the waste bottle in the back of the hood, and contact lab staff to have the bottle removed.

Tank (carboy) full:

e) If the tank (carboy) in the hood being used is full (as indicated on the display panel), do *not* attempt to transport your solution to another hood for disposal. Instead, get an empty waste bottle (these are stored in the lower cabinets beneath the work surface in hoods 10000-3, 1000-4, and 100-9) for disposal of your solution. **Note: This applies to all solutions: acids, bases, solvents, etc.** Be sure to thoroughly deface the original label, and clearly mark the bottle with the words "Hazardous Waste" and the name of solution you are disposing. Cap the bottle, and place the waste bottle in the back of the hood. Contact lab staff to have the bottle removed and the tank emptied.

5. Each bench is equipped with sensors to detect when the waste disposal storage tanks are full; do NOT add waste to a cupsink if an alarm for a full tank is displayed on the hood's display panel. Notify lab personnel immediately if a hood indicates a full waste container. **In the event that the tank is full, users should follow the procedure outlined in section 2.3.4.e above.**
6. When disposing of chemicals (into either the cupsinks or waste bottles), take note of any unusual reactions and notify lab staff immediately. This may signify that the chemical being disposed of requires additional disposal precautions, or that a previous user has introduced problematic reagents into the waste stream. Very serious accidents can occur if chemicals are improperly disposed of, so your observations are important for ensuring lab safety.

Note that the cupsinks have covers with finger holes to allow the cover to be easily lifted; you must remove the cover, pour your waste into the correct cupsink, and replace the cupsink cover. Do *not* attempt to pour waste solutions through the finger holes in the cover. When done discarding a solution, check the area around the cupsink and the hood working surface for drips and clean them up. **All questions about disposal of a chemical must be addressed prior to starting work.** See your advisor, the lab director, or Risk Management and Safety (1-5037). Never leave any chemical container uncapped, especially waste containers.

2.3.1 CHEMICAL WASTE CONTAINER DISPOSAL

Empty chemical bottles or containers should not be left out, but should be disposed of immediately. Solvent and acid bottles should be triple rinsed with water (the rinse water may be dumped down the drain of an acid hood), the label defaced, and then put into the trash bins with the cap off. Other chemical containers may need a pre-rinse prior to a triple water rinse before disposal (e.g. photoresist bottles should be pre-rinsed several times with acetone until it rinses clear.) The proper procedure is: triple-rinse the container, deface the label, and discard in the trash with the cap off.

2.4 HANDLING

1. When chemicals are hand carried, the container should be placed in a secondary container to protect from breakage and spillage.
2. Freight elevators should be used whenever possible to prevent exposure to people on passenger elevators.
3. If a wheeled cart is used, it should be stable under the load and have wheels that are large enough to handle uneven surfaces without tipping over or stopping suddenly.
4. The "tote" part of the cart should have sides to prevent items from rolling or falling off.

2.5 FLAMMABLE LIQUIDS

Solvents are a necessary part of the NDNF laboratory and can be hazardous if handled incorrectly. The laboratory maintains stocks of several solvents. All of these containers are limited to 1 gallon or less to minimize the potential for fires and large spills.

2.5.1 HAZARDS

1. Vapors can form an ignitable mixture in air.
2. Many flammable liquids are solvents and are potentially hazardous by inhalation.
3. Skin contact should be avoided, as irritation or skin absorption are possible with some chemicals.
4. Damage to the eyes can range from irritation to severe damage.

2.5.3 STORAGE

Store all flammable liquids and solvents in solvent cabinets, which are located in the laboratory.

2.5.3 CONTROLS

1. Chemicals must be used in a solvent fume hood.
2. Spills must be cleaned up immediately and the spill area decontaminated.
3. Emergency showers and eyewashes should be used when skin or eye contact occurs. Get first aid attention immediately.
4. Care should be taken when using hotplates to heat flammable liquids. Vapors from overheated solvents can travel under the plate and ignite.

2.6 CORROSIVES

A corrosive chemical is a chemical that causes visible destruction of, or irreversible alterations in, living tissue by chemical action at the site of contact.

2.6.1 HAZARDS

Contact with skin, eyes, respiratory or digestive tract can cause severe irritation or burns.

2.6.2 STORAGE

Store all acids and bases in their respective storage cabinets, several of which are located in the lab.

2.6.3 CONTROLS

1. Wear protective clothing: all users in the cleanroom must always wear gloves, eye protection, and appropriate cleanroom garments. For use of HF, a face shield, apron, and full-length nitrile gloves are required in addition to the standard cleanroom protection.
2. HF use is only permitted in selected hoods in the cleanroom. HF may be used in hoods 100-1, 100-9, 1000-8, and 10000-3 (see cleanroom map on pages 9-10). In addition, HF baths are present in hoods 100-6 (MOS clean hood) and 100-7 (the tube cleaning hood). Note however that both of these hoods are special-purpose hoods for

which specialized training is required before use. They are not available for general use.

3. Never add water to concentrated mineral acids or bases – add the acid or base to water (remember: Always add acid: AAA).
4. In case of skin contact:
   a. Flush affected area with large amounts of water for at least 15 minutes; use the eyewash or safety showers located in the lab.
   b. Remove contaminated clothing.
   c. Seek medical attention.

2.7 REACTIVES

A reactive (unstable) chemical is one, which in the pure state, or as produced or transported, will vigorously polymerize, decompose, condense or will become self-reactive under conditions of shock, pressure or temperature.

2.7.1 HAZARDS

1. Water sensitive chemicals react violently in the presence of water.
2. Pyrophoric materials ignite in air at or below room temperature in the absence of added heat, shock or friction.

2.7.2 STORAGE

1. Store water reactives according to label directions.
2. Pyrophorics should be stored in an atmosphere of inert gas.

2.7.3 CONTROLS

1. Wear proper safety equipment.
2. Read precautionary label.
3. Use only in a hood/glove box.

2.8 OVERVIEW/RECAP – CHEMICAL HANDLING

- **Know the chemicals you use. Safety Data Sheets (SDS) are available.**
- **You must wear gloves at all times in the cleanroom laboratory.**
- **Any use of acids must be performed only at the Acid benches. For Hydrofluoric Acid you must use full apron, nitrile gloves, and a face shield.**
- **NEVER mix acids and solvents – this can result in an explosion.**
- **NEVER add water to acid (NAW) - it can splatter violently.**
- **Always add acid to water (AAA).**
- **Perchloric acid is strictly prohibited.**
- **Hydrofluoric acid (HF) is commonly used in silicon processing. It is especially dangerous in that there is no immediate symptom of pain, but severe damage to the bone can result over a few hours. HF may only be used in designated acid hoods (see diagram on pages 9-10). Take extreme care when using HF. Never put HF or any HF-containing solution in a glass container.**
- **Know where the nearest eyewash station is. If a chemical gets in your eye, call for help and flush eyes for at least 15 minutes.**
- **Solvents are highly flammable. Keep them away from any ignition source.**
- **Properly label all chemical containers: Name, Date, & Contents. Secondary storage containers must include GHS hazard verbiage and/or pictograms**
- **Never leave chemicals unattended without identification.**
- **For reasons of contamination NEVER put any chemicals back into their original containers.**
- **Pour only the necessary amounts of chemicals you are planning to use.**
- **Proper chemical disposal is mandatory.**
    - **HF, SIE-8607 Ta etch, acetic acid, ammonium sulfide, EKC 265 stripper, and iodine complex-containing waste must be put in an appropriate container for pickup & disposal (empty waste bottles are stored in the lower cabinets in the HF-approved hoods in the class 100 and class 1000 areas). The bottle must be clearly labeled with the contents (e.g. "Hazardous Waste, HF"). Do not mix different waste types.**
    - **Acids (except HF and acetic acid) must be collected in the acid waste cupsinks in the hoods in the cleanroom.**
    - **Bases (except ammonium sulfide, EKC 265 stripper, and gold etchant) must be collected in the caustic waste cupsinks in the acid hoods in the cleanroom.**
    - **Solvents must be disposed of in the solvent waste cupsinks located in each solvent hood in the cleanroom.**

2.9 COMPRESSED GASES

Compressed gas cylinders are used for several applications in the lab. While most of these are stored in the gas bunker (room 128A) and are maintained by lab staff, some are in user-accessible spaces and thus basic cylinder safety is essential for all users to understand, since the pressure inside some of these cylinders can exceed 2500 PSI.

Both empty and full cylinders are stored in the loading dock area of the building. Before taking a cylinder, check the associated tag to be sure that it is for you and your project. Do not use another user's or another department's cylinders. The full cylinders of gases are placed on the west wall of the bay under the sign that says "Full Cylinders". Empty cylinders should be returned to the area under the sign that says "Empty Cylinders". Gas cylinders are delivered several times a week, so please plan accordingly for your experiments. Return empty cylinders to the dock area, do not leave them on the gas carts. The gas cart is shared among many users, and must be returned to the loading dock immediately after each use.

2.9.1 HAZARDS

Compressed gases may be flammable, toxic or corrosive. Because of the pressure, a gas cylinder with a broken valve (e.g. from dropping a cylinder) can become a missile capable of penetrating walls.

2.9.2 HANDLING, STORAGE AND USE

1. General Standards
   a. All compressed gas cylinders must be secured to wall or lab bench.
   b. Leave the valve safety caps in place except when the cylinder is in use. Never transport or move a cylinder without the protective cap in place.
   c. Cylinders shall be clearly labeled with their contents. Do not remove or deface labels, decals, etc., provided by the supplier for identification.
   d. A pressure regulator must be used to control the flow of gas from a cylinder.
   e. Never attempt to repair or alter cylinder valves or safety relief devices.
   f. Use only an approved gas cart to transport cylinders. Cylinders are heavy and can be difficult to properly position. If you need help, contact laboratory personnel or other lab users for assistance.
   g. All cylinders entering the cleanroom must be wiped with an alcohol solution in the airlock (as does any other item entering the lab).
   h. Empty cylinders should be returned to the dock area for pick up. They may not be left on a cart.

2. Pressure Regulators and Gas Fittings
   Regulators and gas fittings are designed specifically for different families of gases and different purity levels. Use only fittings and components designated for the gas and purity level you are using. The proper procedure for making connections depends on the exact type of fitting being used; users must consult with lab staff before attempting to modify or adjust any plumbing in the laboratory. Some general princples to apply in working with compressed gases include:
   a. Threads and surfaces must be clean and tightly fitted. Do not lubricate.

b. Tighten regulators and valves firmly with the proper size wrench (Avoid using adjustable wrenches or pliers as they can damage the fittings). Do not force tight fits.
c. Open valves slowly, and do not stand directly in front of the gauges, as gauge face may blow out if pressures increase too rapidly. Do not attempt to force frozen valves.
d. Shut off cylinders when not in use.

3. Leak Testing
   Cylinders and connections should be tested by "Snoop," a soapy water solution, or by using a leak tester for high purity applications.

2.10 LIQUID NITROGEN

Liquid nitrogen has a temperature of 77K (-196 C). In contact with objects at room temperature, it converts to the gas phase very quickly. It does not contain oxygen, and thus can cause asphyxia if released in a confined area. Contact with this product may cause frostbite or freeze burns. When dispensing liquid nitrogen (LN2), ensure that the area you are working in is well ventilated and that you have the proper personal protective equipment (PPE).

Individuals working with liquid nitrogen should wear eye protection and gloves rated for cryogenic service or use protective thermal pads to avoid frostbite "burns".

Liquid nitrogen is available through a "house" system that is plumbed into the building from a large exterior tank. Dewars for transporting the liquid to other labs within the building can be filled from the house LN2 system at the fill station in the loading dock area. The containers should be brought up using the freight elevator. Users must be trained in the proper use of the LN2 fill station prior to use, and must log the quantity and account number to charge for the cost of the LN2.

When transporting a liquid nitrogen dewar, ***ALWAYS PULL THE CONTAINER!*** Never push a container. Pushing a dewar may cause it to tip over, leading to a large release of nitrogen and an asphyxiation hazard.

3.0 PERSONAL PROTECTIVE EQUIPMENT (PPE)

The Laboratory Director and/or the PI for the user (or authorized representative) are responsible for the selection of personal protective equipment, acquiring approved equipment, maintaining availability, and establishing cleaning and disposal procedures. Protective clothing must be removed before leaving the lab.

1. Lab users must know the types of protective equipment available and use the proper type for each job. Everyone, including visitors, must wear the appropriate protection in the lab.
2. Wear appropriate gloves when handling hazardous chemicals.

3.1 EYE PROTECTION

1. Safety glasses with side shields are required at all times.
2. Face shields with safety glasses underneath or chemical splash goggles are required when transferring or pouring acid or caustic materials, or where a potential splash exists.
3. Full face shields are required whenever HF is being used.
4. Inspect before each use the eye and face protection you plan to use. If there is any damage, do not use it. Notify laboratory personnel immediately so that the defective item can be replaced.

3.2 GLOVES

1. Approved gloves must be worn at all times in the lab.
2. Gloves must be removed in the gowning room before leaving the lab. In addition, specialty gloves may be required for particular processes:
   a. Heat resistant gloves shall be used for handling hot objects.
   b. Low temperature gloves specifically designed for cryogenic use shall be worn when handling materials like dry ice or liquid nitrogen.
   c. Full-length nitrile gloves are to be used when handling HF.
3. Before each use, gloves are to be inspected for damage and contamination. If there is any damage, holes, or contamination do not use them and replace them immediately. If replacements are not available in the lab, notify laboratory personnel immediately so that replacements can be supplied.
4. After use, shared gloves (e.g. nitrile gloves for HF use) are to be left in the appropriate hood to dry for the next user.

3.3 CLOTHING

Although a gowning protocol is strictly enforced for the lab, there are additional restrictions on user clothing that must be observed in order to provide adequate protection from potential hazards:

1. No sandals or open-toed shoes are to be worn in the lab. This applies even though booties will be worn; these types of shoes do not provide adequate protection from spills or dropped objects.
2. The shoe should have a non-skid sole and should have a reasonable heel height.
3. Gowning is to be performed per the protocol described previously.

3.4 RESPIRATORS

If any user has a need for a respirator, please consult with your PI and Risk Management & Safety for the selection of this Personal Protective Equipment (PPE).

3.5 EMPLOYEE TRAINING (PPE)

Employees should not use any Personal Protective Equipment until they have received instruction on the proper selection, use, and limitations of the equipment.

4.0 EMERGENCY EQUIPMENT AND PROCEDURES

4.1 GENERAL

Each laboratory user must be familiar with the location of the fire alarms (pull stations), fire extinguishers, gas system emergency shutdown buttons, safety showers and eyewashes, as well as telephones, first-aid and spill containment kits, and emergency exits. These locations are noted on the emergency equipment laboratory layout on page 30.

4.2 SAFETY SHOWERS AND EYE WASHES

There are three safety showers and four eye wash stations in the laboratory. There is a safety shower in each of the Class 100, 1000, and 10,000 areas. Eye washes are also located beneath each safety shower, and an additional eye wash is located near the airlock in the class 1000 area. See the emergency equipment lab layout on page 30. The use of the eye washes and safety showers will trigger an alarm and a flashing yellow beacon. If you see this, please go to offer assistance to the person in the shower or eye wash.

4.3 LABORATORY ATTIRE

Any cleanroom garment that has been exposed to a chemical spill or splash should be removed immediately. Although removing clothing in the cleanroom is prohibited under normal circumstances, in the event of a chemical spill or other emergency the health and safety of lab users is much more important than the cleanliness of the lab. The severity of contamination will determine how much of the clothing will be removed. Temporary clothing is available for emergencies. By each safety shower are plastic bags containing socks, sweat pants, and sweatshirts (of different sizes) to wear while seeking medical attention after use of the safety shower. Sandals are located in the gowning room. Additionally, a blanket is available in the gowning room if dressing is difficult.

4.4 EMERGENCY PROCEDURES

No single emergency plan will be adequate for all emergency situations. The most important component of properly handling an emergency is knowledge. **If a fire alarm (loud alarm, white strobes on ceiling) or the toxic gas alarm (loud alarm, blue strobes on wall) sounds, all persons are to leave the laboratory and building immediately.** *Never* assume that it is a drill. In the event of a toxic gas or fire alarm leave the lab immediately using the emergency exits shown on page 30. Do NOT attempt to leave the lab through the gowning area or attempt to de-gown; your first priority is to get out of the lab in an emergency. When you leave the building, all personnel should assemble with the cleanroom staff at the northwest corner of the building. In the event of inclement weather, pleas assemble in the south entrance of McKenna Hall. When the fire department issues the "all clear" and allows you back into the building, place your cleanroom garments in the laundry hamper and get new ones before re-entering the lab (since by wearing your garments outside the lab they have been contaminated). In general, if there is any question about any situation or something happening in the laboratory, always ask (ND Fire Dept., your PI, Lab Manager, or others). It is better to err on the side of caution.

If you detect a fire in the laboratory, pull the nearest fire alarm and exit the lab. As outlined above, do not attempt to de-gown; use the emergency exit routes. Although the lab is equipped with an automatic toxic gas monitoring and alarm system, if you detect a hazardous

condition related to the lab gas supply, press the "specialty gas shutdown" buttons (see page 30 for locations). This will set off a loud alarm and will lead to evacuation of the lab.

Call campus security (wired line: 911, cell phone: 631-5555) for all emergencies. They will dispatch the Police, Fire Department, medical aid, or Risk Management and Safety.

When reporting an emergency, give as much information as possible, such as:

1. Location and type of emergency
2. Name of victim (if necessary)
3. Your name
4. Extension number of caller
5. If a chemical is involved, write down the name to give to emergency personnel.
6. If possible, remain at the scene to help explain what happened.

4.5 FIRST AID and MEDICAL ATTENTION

Accidents or injuries should be treated, and reported, promptly. As of this writing, students (graduate or undergraduate) who are injured as part of a class-related activity should report to University Health Services/St. Liam's Hall. Undergraduate students performing undergraduate research should also report to St. Liam's Hall. For any paid lab personnel (staff, graduate research assistants; salary or stipend support but not part of a course) should report to the ND Wellness Center during working hours, or Med Point 24 (6913 N. Main St., Granger) outside regular business hours. **See section 6.3 of the UND Chemical Hygiene Plan for the latest list of approved medical service providers.** For accident victims who need medical care beyond first aid, call campus security (911 on wired phone, 631-5555 on cell phone) for transportation to the proper medical facility. After hours, security (911 on wired phone, 631-5555 on a cell phone) should be contacted for all significant injuries. In any case where you are not sure of the severity of the injury, contact campus security (911, 631-5555). In no case should an injured person seek treatment alone; call campus security for transportation. All incidences of injury in the lab must be reported the lab director within 24 hours.

To assist with treatment of injuries, first aid kits are available in the laboratory. The location of these kits is shown on page 30. These kits include bandages, antiseptic wipes for cleaning wounds, clean gloves to avoid exposure to bodily fluids, calcium gluconate for treating HF burns (located in a tube on top of the kits), and a mouth barrier for CPR. In addition, calcium gluconate is also available on top of each "HF approved" hood in the class 100, 1000, and 10,000 spaces, the equipment airlock, and the gowning room. A defibrillator is available outside of the lab, in the hallway near the "Kitz Kafe" and stairwell.

FIRST AID PROCEDURES

1. CHEMICAL BURNS: Flush the affected area with cold water for at least 15 minutes; remove affected clothing. Flush eye for at least 15 minutes at an eye wash station or sink.

   Special case: HF

   In the event of contact with HF, wash/flush the affected area for 15 minutes, and immediately apply calcium gluconate gel liberally to the affected areas (including on/around/under fingernails), massaging the gel into the skin. Seek medical

attention immediately. Re-apply the calcium gluconate as indicated above every 15 minutes until medical assistance is received. Seek to avoid secondary HF exposure or transfer by having the victim wash area and apply the gel themselves, if possible. If assistance is required, the person assisting should wear appropriate HF-protective gloves and other safety equipment. Discard the tube and any unused gel after use, since HF residue may have gotten on the tube.

2. THERMAL BURNS: Immerse the burned area in cold water or apply ice until the pain stops. Cover with a sterile dressing.
3. POISONS: Call the Poison Center (1-800-382-9097) for assistance in administering poison antidotes.
4. BLEEDING: Hold a clean cloth pad directly on the wound and apply hand pressure. Apply a tourniquet only as a last resort.
5. FIRES: Put out burning clothing or hair with a fire blanket or water. If these resources are not available, make the victim roll on the ground to put out the flames.

4.6 CHEMICAL SPILLS

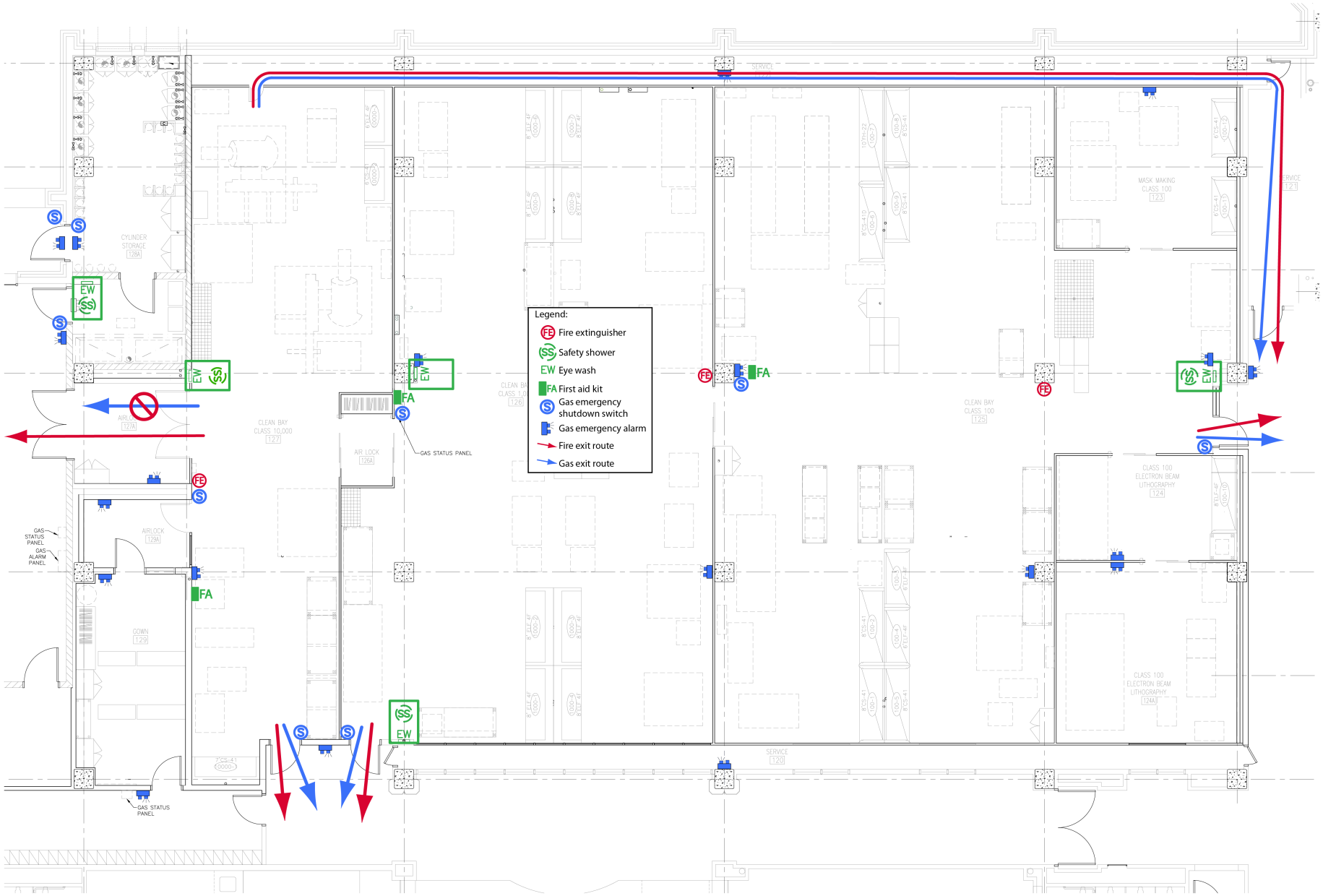
When spills occur, it is necessary to take prompt and appropriate action. Appropriate action will depend on the severity of the hazards associated with the particular chemical

1. If the spill is minor and of known limited danger, begin the cleanup operation immediately.
2. If the spill is unknown in chemical composition or potentially dangerous (explosive, toxic fumes), evacuate the room and call Risk Management and Safety at 1-5037 during business hours (8-5 M-F) or campus security at 911 or 631-5555 on weekends or outside of business hours.
3. If it is suspected or known that the spill is extremely dangerous:
    a. Call Security (911) who will alert the Fire Department and Risk Management and Safety.
    b. Evacuate the building by pulling the nearest fire alarm pull station. See the Fire Alarm & Safety Item Location drawing in the appendix for location.

4.7 CHEMICAL SPILL CLEANUP

Spill control (outside of a processing hood) begins by using absorbent material (such as wipes or absorbent pillows in the spill kits) on the spill. Spill cleanup kits are available near the fire extinguishers within the lab (see diagram on page 30). Note that because the cleanroom floor is elevated with perforations in it for airflow, chemical spills must be cleaned up not only on the normal (elevated) floor surface, but also on the sub-floor beneath. When using a spill kit, after allowing the chemical to absorb, scoop up the absorber material and deposit it into a plastic disposal bag. Wipe up the contaminated surface with water and a sponge immediately and place in the disposal bag. Be sure to clean both the elevated floor as well as the concrete floor underneath. Tie the bag to close it and take it to the equipment airlock. Notify lab staff of the spill; be sure to indicate the chemicals involved and the location. Call Risk Management and Safety (1-5037) and lab staff for disposal procedure or pickup. If in doubt about the proper spill cleanup procedures, call Risk Management and Safety.

For spills that occur inside a processing hood, soak up the spill using cleanroom wipes. Thoroughly rinse the affected work surface with water (DI), and wipe dry with a cleanroom wipe. Prior to disposing of the wipes used to clean up, triple-rinse them in a sink with DI, then dispose of in the trash. Remember that it is important to leave the processing surfaces clean and uncontaminated, so be thorough in your cleanup efforts.


Legend:
Fire extinguisher
Safety shower
EW Eye wash
FA First aid kit
Gas emergency shutdown switch
Gas emergency alarm
Fire exit route
Gas exit route
CYLINDER STORAGE 128A
CLEAN BAY CLASS 10,000 127
AIR LOCK 126A
CLEAN BAY CLASS 100 126
CLEAN BAY CLASS 100 125
MASK MAKING CLASS 100 123
CLASS 100 ELECTRON BEAM LITHOGRAPHY 124
CLASS 100 ELECTRON BEAM LITHOGRAPHY 124A
AIRLOCK 129A
COWN 129
SERVICE 120
GAS STATUS PANEL
GAS ALARM PANEL

5.0 LABORATORY USER ORIENTATION & TRAINING

All new users of the laboratory must read the "Notre Dame Nanofabrication Facility, Laboratory Operations & Safety Procedures Manual", (this document) before access to the laboratory and equipment is granted.

5.1 CHEMICAL TRAINING

It is the responsibility of the laboratory user to become familiar with the chemicals that they are using.

5.2 EQUIPMENT TRAINING

There are numerous users pieces of complex equipment in the laboratory that require specialized training for proper use. In addition, many tools in the lab have specific requirements for users to log their activities. In general, you may not use a piece of equipment on which you have not been trained by a member of the lab staff. You may not be trained by another lab user, and you may not train others to use equipment. Some of the equipment is equipped with computer-controlled access control (via iLabs) to prevent unauthorized use. However, training is required for all tools—even those without access control—and users should not assume they are authorized to use any equipment in the lab for which they have not been explicitly trained. If you do not follow the procedures for tool usage, your access to the will be revoked.

General principles:

1. If you sign up to use equipment and do not show up within 10 minutes of the time signed up for you forfeit your reservation.
2. Only authorized users are allowed to sign up and use equipment.
3. If you are not an authorized user, DO NOT USE THE EQUIPMENT!
4. Authorized users are NOT allowed to train others.
5. Report any problems as they occur. When reporting a problem, give as complete a description of the problem as possible ("It's broken" or "doesn't work" is not very helpful). Please report all problems to staff-ndnf-list@nd.edu.
6. If you use the lab for both coursework and research, be sure that you card in/out with the correct badge (i.e. use your research badge for your research time, and your course badge only for course-related usage).
7. If you pull out equipment, racks, carts, step stools, etc. replace them in their proper position.
8. Keep the area around instruments and equipment clear of obstructing materials.
9. Equipment with frayed electrical cords should be reported immediately.

6.0 LASER SAFETY

Lasers pose potential hazards to users. The laboratory has several pieces of equipment that use lasers (GCA AS-200 Stepper, Mann 3696 step and repeat, Mann 3600F pattern generator, Gaertner ellipsometer, Metricon prism coupler). Care should be taken when working around any of this equipment to avoid any undue exposure to the laser light.

7.0 THE NDNF LABORATORY

7.1 LABORATORY LAYOUT

All users should be aware of the layout of the laboratory with respect to the safety features of the lab, as shown on page 30. This manual applies to both the cleanroom spaces as well as the wirebonding area (room B06) and dicing saw area (room 132).

7.2 LABORATORY ALARMS

There are various alarms and safety features built into the building and equipment for the Nanofabrication Laboratory.

7.2.1 BUILDING OR LABORATORY ALARM

When a fire or fire alarm occurs for the laboratory, always leave immediately (see section 4.4 above). Never assume it is a false alarm or drill. Likewise, leave the lab immediately if toxic gas alarm sounds (indicated by flashing blue strobe lights).

7.2.2 EQUIPMENT ALARMS AND EMO SWITCHES

Many pieces of equipment in the lab are equipped with alarms to indicate equipment status, as well as emergency off switches. Since the equipment-specific alarms in the lab are generally notification of a minor fault or a process problem (as opposed to a safety issue), you should notify lab personnel or other affected users (e.g. faculty advisor, other lab users) by email, voice mail, or in person. Outside of daytime working hours for the lab staff, a voicemail or email message to lab personnel and other affected users is sufficient unless you believe that the situation is more serious than a routine condition. Examples of non-routine problems that require more aggressive notification include fire in equipment, water leaks from any equipment or facility, equipment making unusual noises, etc. In non-routine cases, contact the lab manager (Mark Richmond) or lab director at home by telephone. Fires should always be reported to the Fire Department by pulling the fire alarm and calling 911 from a wired phone or 631-5555 from a cell phone.

The EMO switches on equipment or the specialty gas system or the liquid nitrogen system should be pressed only in an emergency. Emergencies include a fire or smoke, an injury to anyone in the lab associated with a particular piece of equipment, a large spill of chemicals or water near or inside a piece of equipment that might be a fire or electrocution hazard, or other similar situations. Your sample being damaged does not constitute an emergency.

8.0 REFERENCES

Chemical Hygiene Plan: https://riskmanagement.nd.edu/assets/205207/chp_final_2016.pdf

APPENDIX A

Definitions and Terms
The following terms are often encountered when reading about the properties of chemicals and the toxicity of chemicals, for example, on the Safety Data Sheets. Simple definitions are included here to help you understand the properties of common chemicals when referring to the SDS or other references. This is not intended to be a complete reference on toxicology or chemical safety.

Acute Effects refers to the duration of the symptoms. Acute means symptoms lasting a few hours or days. Again, it has nothing to do with the severity of the effects.

Acute Exposure as used in toxicology refers to a short-term exposure. It has nothing to do with either the severity of the exposure or the severity of the effect. The type of exposure occurring during an accidental chemical spill is properly described as an acute exposure.

Allergies and Hypersensitivity are reactions by particular individuals to particular chemicals, caused by heredity or prior overexposure. Hypersensitive individuals should avoid exposure to the offending agents.

Carcinogen- A substance producing or inciting cancerous growth.

Chronic Effects are long-term effects, manifested by prolonged duration and continuing injury.

Chronic Exposure as used in toxicology refers to a long-term exposure. Again, it has nothing to do with the severity of the exposure, the severity of the consequences, or the duration of the consequences. Chronic exposures can be the result of chemicals in the workplace, the home, or the environment. Chronic exposures are usually the result of carelessness, ignorance, or neglect, and not the result of an accident.

Combustible Liquids: Combustible liquids shall mean any liquid having a flash point (closed cup) at or above 140° F and shall be known as Class III liquids. Class IIIA shall include those having flash points (closed cup) at or above 140° F and below 200° F. Class IIIB shall include those having flash points (closed cup) at or above 200° F.

Compressed Gas - any material or mixture having in the container a pressure exceeding 40 psia at 70 degrees F, or a pressure exceeding 104 psia at 130 degrees F; or any liquid flammable materials having a vapor pressure exceeding 40 psia at 100 degrees F.

Corrosive Material - any liquid or solid that causes visible destruction of human skin tissue or a liquid that has a severe corrosive rate on steel.

Corrosive Wastes - a material is corrosive if it is either highly acid or highly alkaline. The government defines limits of acidity at pH 2.0 and alkalinity at pH 12.5. Any waste that does not fall within these limits is considered corrosive.

Exothermic Reaction- A reaction, which produces heat (releases energy).

Explosive - any chemical compound, mixture, or device, the primary or common purpose of which is to function by explosion, i.e., with substantially instantaneous release of gas and heat, unless such compound, mixture, or device is otherwise specifically classified.

Flash Point: Flash point is the temperature at which a liquid has a vapor pressure sufficient to for an ignitable mixture in the air near the surface of the liquid. Open cup flash points vary several degrees higher than closed cup flash point.

Flammable Liquids: Flammable liquids shall be divided into two classes of liquids as follows:

1. Class I liquid shall include those having flash points below 100° F.
2. Class II liquids shall include those having flash points (closed cup) at or above 100° F and below 140° F.

Hazardous Material - is any solid, liquid or gas that is either ignitable, corrosive, reactive, or toxic.

Hazardous Waste - is any solid or liquid waste that is either ignitable, corrosive, reactive or toxic.

IDLH - Immediately Dangerous to Life and Health. This level represents the maximum value for which a 30 minute exposure will result in no irreversible or escape impairing effects, i.e. the maximum level that will not cause you to pass out or sustain irreversible organ damage. It is the value most appropriate to sudden, one time accidental exposures. For your information, a short table of values for relevant chemicals is listed below.

IDLH for several Chemicals

- Ammonia 500 ppm
- Carbon Monoxide 1500 ppm
- Chlorine 25 ppm
- Hydrogen Fluoride 20 ppm
- Diborane 40 ppm
- Phosphine 200 ppm

Ignitable Wastes - waste is ignitable if it can catch fire easily under conditions of routine handling. Chemicals such as fuels, solvents, paint and chemical wastes, and explosive wastes may often be ignitable.

Irritating Material- a liquid or solid substance which upon contact with fire or when exposed to air gives off dangerous or intensely irritating fumes, but not including Class A poisonous materials.

Local Effects occur in a small area, at the place of contact.

Local Exposure refers to exposure limited to a small area of skin or mucous membrane.

Mutagen- Capable of inducing mutations.

SDS - Safety data sheet.

NIOSH - National Institute of Occupational Safety and Health

Nonflammable Gas - any compressed gas other than a flammable compressed gas.

Organic Peroxide - any organic compound containing the bivalent -0-0- structure and which may be considered a derivative of hydrogen peroxide where one or more of the hydrogen atoms have been replaced by organic radicals must be classed as an organic peroxide.

OSHA - Occupational Safety and Health Administration.

Oxidizer - a substance such as chlorate, permanganate, inorganic peroxide, or a nitrate, that yields oxygen readily to stimulate the combustion of organic matter.

PEL - The permissible exposure limit (PEL), (or TLV Threshold Limit Value). Workers may be exposed to these substances for up to 8 hours per day 5 days per week. These values are published by OSHA, NIOSH, and ACGIH (American Conference of Governmental Industrial Hygienists)

Poison A - Extremely Dangerous Poisons: Poisonous gases or liquids of such nature that a very small amount of the gas, or vapor of the liquid, mixed with air is dangerous to life.

Poison B - Less Dangerous Poisons: Substances, liquids, or solids (including pastes and semisolids), other than Class A or Irritating Materials, which are known to be so toxic to man as to afford a hazard to health during transportation; or which, in the absence of adequate data on human toxicity, are presumed to be toxic to man.

PPE - Personal protective equipment.

Pyrophoric Material - Any material that ignites spontaneously in dry or moist air at or below 130 degrees C.

Reactive Wastes - Substances, which can explode or release poisonous vapor on contact with air, water, or other neutral liquids. Reactive wastes may often be produced in metal heat-treating and electroplating operations, in the production of explosives, in some leather finishing operations, and in many chemical manufacturing processes.

STEL - Short Term Exposure Limit. This value is the maximum concentration to which workers can be exposed for a period up to 15 minutes continuously without suffering from: irritation; chronic or irreversible tissue change; or narcosis of sufficient degree to increase accident proneness, impair self-rescue, or materially reduce work efficiency, provided that no more than four excursions per day are permitted, with at least 60 minutes between exposure periods, and provided that the daily maximum exposure level also is not exceeded.

Systemic Effects occur throughout the body, or at least away from the point of contact.

Systemic Exposure means exposure of the whole body or system, through absorption, ingestion, or inhalation.

Teratogen- A substance causing damage or death to a fetus.

TLV - Threshold limit value. This is actually TLV-TWA (time weighted average) but is commonly called just TLV. It is the (averaged) level to which you can be exposed 8 hours a day, 5 days a week forever, without adverse health effects. These levels are set by ACGIH (governmental and industrial hygienists), and adopted into law by OSHA (Occupational Safety and Health Administration). This level is most relevant to chronic (long term) exposure to chemicals in the work place. Short term exposures in excess of TLV are thus not necessarily hazardous.

Toxic Wastes - wastes that are poisonous to human beings or other animals. Some are poisonous to the touch; others are harmful if inhaled; still others are toxic only if swallowed. Some produce immediate sickness, while others may not cause obvious symptoms for months or even a year.

APPENDIX B

Emergency Action Plan: Stinson Remick

A. General Evacuation Procedures: All occupants are required to evacuate the building immediately when a fire alarm sounds or other evacuation signal is given. Fire doors should **never** be blocked open and doors and stairwells should not be obstructed. **In the event of uncontrolled fire, smoke, chemical spills or other emergency situations, building occupants should:**

1. Notify Security Police Dispatch **(911** or **574-631-5555)** and provide:
   a. Your name
   b. Building
   c. Exact location of emergency
   d. Type and extent of emergency
2. Close all the doors to the room containing the fire or other hazard when leaving.
3. Activate the fire alarm at the nearest manual station located in the hallway, if possible.
4. NEVER USE AN ELEVATOR IN THE CASE OF SMOKE OR FIRE.
5. Leave the building through the nearest exit. Some buildings have evacuation routes posted in the hallways.
6. Meet at the designated assembly location outside the building. Do not assemble in the fire lanes or near the building.
7. Do not re-enter the building until given clearance from the Notre Dame Fire Department or its designee.

B. If you are trapped in a building because of smoke, heat, flames, or other hazards and cannot find an escape route:

1. Close the door(s) in your room. Seal door cracks and ventilation grills with cloth or wetted towels or clothing, if possible.
2. Contact Security at 911 and give your exact location to the Dispatcher.
3. Smoke accumulates at the ceiling and works its way down. Stay close to the floor where the air is fresh.
4. Remain calm, help is on the way.

C. Persons Needing Assistance

During both evacuation drills and an actual emergency, persons needing assistance should be helped to the nearest fire escape window or door or stairway door for their increased protection and to make rescue easier for trained emergency personnel. In no case should emergency action obstruct exit routes or subject others to injury.

D. Rescue/Medical Response

To the extent possible, rescue and/or medical duties should be performed only by qualified persons including but not limited to: ND Security Police, ND Fire Department or other trained medical personnel, including the Red Cross.

E. Weather Emergencies

1. **Flood** - In the event of a flood in or around a building, all occupants should move to the highest level of the building with points of exit. Evacuate quickly, quietly, and in an orderly fashion as directed by Security Department or its designee.

2. **Lightning -** A typical lightning bolt contains several hundred million volts at 30,000 or more amperes. Avoid windows during an electrical storm. Avoid void using electrical appliances and stay away from all metal objects during a storm. Do not go outside.

3. **Tornadoes -** A tornado warning is issued when a tornado has been sighted or when the NWS issues a tornado warning for St. Joseph County. Do not leave the building during a tornado warning. All occupants should move to the B-Level of SR. Get in a crouched position, head between knees with hands protecting the back of the head.

4. **Warning Sirens** - Are designed for notifying persons outdoors of imminent severe weather. In addition, the University will issue an ND Alert notifying the campus of the threat.

5. **All Clear** - Once the NWS lifts the warning, a second, "All Clear" ND Alert message will be sent using the public address systems on campus. The notification is also available via radio or television.

Warning sirens are tested at 11:30am
1st Thursday of each month.

F. Active Shooter / Violence

If an active shooter occurs in your vicinity, think "**OUT!**"

1. **Figure Out:** Determine what is going on and where.

2. **Get Out:** If you are in a building and there is an accessible escape path, attempt to leave the premises.

   a. Have an escape route and plan in mind; leave your belongings behind; follow police instructions
   b. Call NDSP if possible and provide what information you can, including the location and number of shooter(s), a description of the shooter(s), any weapons used and potential victims.

3. **Hide Out:** If evacuation is not possible, find a place to hide where the shooter is less likely to find you. Hide in an area out of the shooter's view; provide protection; lock and blockade the doors if possible; block entry to your hiding place; and silence your cell phone.

   In all cases, call NDSP as soon as you can safely do so and provide what information you can; wait for law enforcement.

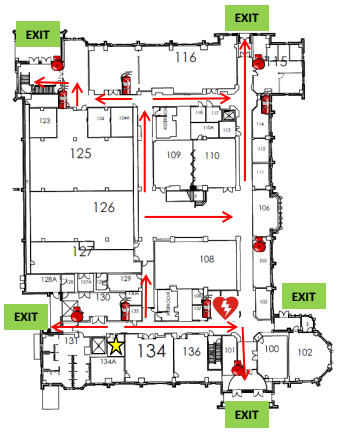
4. **Take Out:** As a last resort, only when your life is in imminent danger, attempt to disrupt or take out the shooter.
   a. Act as aggressively as possible against him/her; yell, throw items, and commit to your actions.

G. Exit Instructions & locations of Critical Items

See the Building Diagram for more information.

For all evacuations please meet on the Northwest corner of Stinson Remick Hall. For bad weather meet in McKenna Hall (next to Stinson Remick on the North end of the building).

Stinson Remick Hall 1stFloor



To Report an Emergency:
- **911 from a campus phone**
- **(574) 631-5555 from a cell phone**

Nearest Heart Defibrillator(A.E.D):
- **Stinson Remick Hall, 1st floor near Cafe**

Legend
- Pull Station
- Fire Extinguisher
- Direction of Egress
- You Are Here
- A.E.D.

IN CASE OF FIRE:
- Use the pull station or contact NDSP
- Calmly proceed to the closest exit and exit the building.
- Do not use the elevator
- Gather in your **Emergency Assembly Area** located at:
  - **Northwest corner of Stinson Remick**
  - **South entrance of McKenna Hall if the weather is poor**

IN CASE OF A WEATHER-RELATED EMERGENCY:
- Seek shelter in the center of the lowest level of the building;
- Lower level storage area
- Stay away from windows

IN CASE OF VIOLENCE:
- If incident is occurring in your building, contact NDSP if possible;
- Seek shelter in a lockable or securable room, preferably without windows;
- Remain in secure location until "all clear" is given

Lab User Information and Agreement Form

In case of emergencies or important questions, we must have contact for all lab users. Please fill out all applicable information, and return to the laboratory manager.

Name: _____

Email Address:_____

Your office room number and phone: _____

Campus or local home phone number: _____

Title (undergrad, grad student, postdoc, etc):_____

Advisor: _____

FOAPAL (xxxxxx-xxxxx-xxxxx-xxxxx) for charges: _____
(if requesting multiple badges, supply separate FOAPAL numbers for each badge)

General area of research or course number: _____

Who to notify in case of emergency:

Name: _____ Relationship _____

Phone Number: _____

Safety Manual Agreement

I have read and understood the ***Notre Dame Nanofabrication Facility – Laboratory Operations & Safety Manual, Rev. 14, August 18, 2021.*** I will abide by all laboratory regulations and understand that failure to abide by the regulations and failure to be responsible for others working in the laboratory can result in the loss of laboratory privileges. I understand that an access ID badge is University property, and will return it when lab access is no longer required.

Name (Print) _____

Signature _____

Date _____

Emergency Action Plan Acknowledgement

I have read and understood the Emergency Action Plan, appendix B.

Initials:_____ Date: _____

ComplyND – date of most recent general lab training/refresher: _____
Cleanroom safety overview/refresher (with Prof. Fay) date: _____
Badge # (middle 5 digits) _____

Rev 14 8/18/21