NYU NanoFab Cleanroom

Safety Manual

NYU NanoFab Cleanroom

Table of Contents

NYU NanoFab Cleanroom

1. Introduction

This document was developed for the New York University (NYU) NanoFab Cleanroom to provide guidance to Cleanroom staff and laboratory users. It was developed to be in compliance with the OSHA Laboratory Standard, 29CFR 1910.1450 and NFPA 318. It is expected that all users of the Cleanroom become familiar with its contents and practice its policies and procedures.

1.1. Description

The Cleanroom is contained within ~ 2,000 square feet of laboratory space, and has a Class 1000 High Efficiency Particulate Air (HEPA) filtration system. The Cleanroom houses semiconductor fabrication equipment and also contains toxic, flammable, and corrosive process gases, as well as other hazardous chemicals. The Cleanroom is humidity and temperature-controlled due to the sensitive nature of the chemicals contained inside as well as the NanoFab processes which occur.

The following equipment will be housed in the Cleanroom for all NanoFab purposes:

i. Suss Contact Aligner
ii. Raith 150^{TWO} E-Beam Pattern Generator
iii. KJLC Proline 75 ALD System
iv. Nano-36 Thermal Evaporation System
v. Proline 75 PVD System
vi. Nanoquest III IBE System
vii. Nikon LV150N Optical Microscope
viii. Filmetrics F40-UV Film Thickness Monitor
ix. PlasmaEtch O_2 Plasma System
x. UVOCS UV Ozone System

1.2. Location

The Cleanroom is located in Rooms 819A, 819F, 819E, 819D and 819C of the 8th floor in the 6 MetroTech Center Building, Brooklyn, NY 11201.

2. Cleanroom Access

Primarily, there will be 3 types of users:

i. Internal Academic: NYU students and Principle Investigators (PIs)
ii. External Academic: non NYU students and Principle Investigators
iii. External Industrial:- users employed by private industry or local/state/federal government

Users can gain entry to the Cleanroom by using their NYU issued ID as a keycard. A user's Net ID and N Number can be used to grant access by the NYU Information Systems Office. For External Academic and Industrial users, the completion and submission of an Affiliate Management/Point-of-Interest form, along with a copy of a picture ID and a letter of affiliation intent from the Chemical and Biomolecular Engineering department will be required for submission to the Department of Human Resources at the Tandon School of Engineering to obtain an NYU ID. External users can then be granted access by the NYU Information Systems Office. A printable copy of the Affiliate Management/Person-of-Interest form can be found on the NYU NanoFab website: http://microsites.engineering.nyu.edu/NanoFab/

2.1. NYU (EHS) Lab Safety and Hazardous Waste Disposal training

The following topics are covered in both the Lab Safety and Hazardous Waste Disposal training:

Lab Safety

i. The Occupational Safety and Health Administration (OSHA) Lab Standard
ii. NYU Chemical Hygiene Plan
iii. Hazard Identification
iv. Labels and Safety Data Sheets (SDS)
v. Chemical Storage and Handling
vi. Personal Protective Equipment (PPE)

Toxicology and Risk Assessment *Hazardous Waste*

i. Waste Minimization
ii. Spill Procedure

The procedure to gain physical access to the Cleanroom will vary depending on the type of user. All users will be required to complete the NYU Environmental Health and Safety (EHS) Lab Safety and Hazardous Waste Disposal training. Information on the NYU EHS training schedules, as well as other NYU EHS information can be found at: https://www.nyu.edu/life/safety-health-wellness/be-safe/environmental-health-and-safety/training.html.

2.2. NYU NanoFab Cleanroom Safety Exam

The following topics are covered in the NYU NanoFab Safety Exam:

i. General Equipment Safety
ii. Chemical Use and Safety Procedures
iii. Cleanroom Dress Code

A user will only gain entry upon scoring an 80 % or better on the exam.

2.3. User Account Form

All Cleanroom users must fill out the User Account Form, which can be found on the NYU NanoFab Cleanroom's website:http://microsites.engineering.nyu.edu/nanofabrication/request-an-account/. Once the relevant information fields have been filled out, and the form submitted, the NYU NanoFab will review the information. If the fabrication processes and chemicals used are deemed to be suitable for use inside the space, the user will be granted permission to enter the Cleanroom, assuming that all other entry requirements have been satisfied. Although entry has been granted, users will still be required to become trained and certified on particular pieces of equipment before full equipment access will be granted. The training schedule pertaining to the specific equipment is located on the NYU NanoFab Website:

http://microsites.engineering.nyu.edu/nanofabrication/equipment-training-schedules/

2.4. Badger Login

Badger Lab Management System (LMS) will be used to keep track of tool usage and purchases made through the cleanroom for ancillary items, such as wafers, tweezers, cleanroom pens, and cleanroom paper. Once a user account has been approved, the user will be added to the Badger LMS. Instructions on logging into the Badger LMS can be found on the NYU NanoFab website at: http://microsites.engineering.nyu.edu/nanofabrication/badger-lms-login/.

2.5 Hours of Operation

The NanoFab Cleanroom will be open 24 hours a day and 7 days a week to approved users. Users who intend to use the Cleanroom after hours (after 6pm-7am on weekdays and/or on weekends) will be required to obtain a Fire Department of New York (FDNY) Certificate of Fitness, C-14. Information

regarding the FDNY C-14 exam can be found at: https://www1.nyc.gov/nycbusiness/description/cof-c14. Users are required to use the "Lab Buddy" system if using the NanoFab afterhours where at least one other person must be in the Nanofab.

Users are **NOT** allowed to badge individuals who have not been properly trained into the lab at any time. There are **no exceptions** to this policy.

2.6. Floor Plan

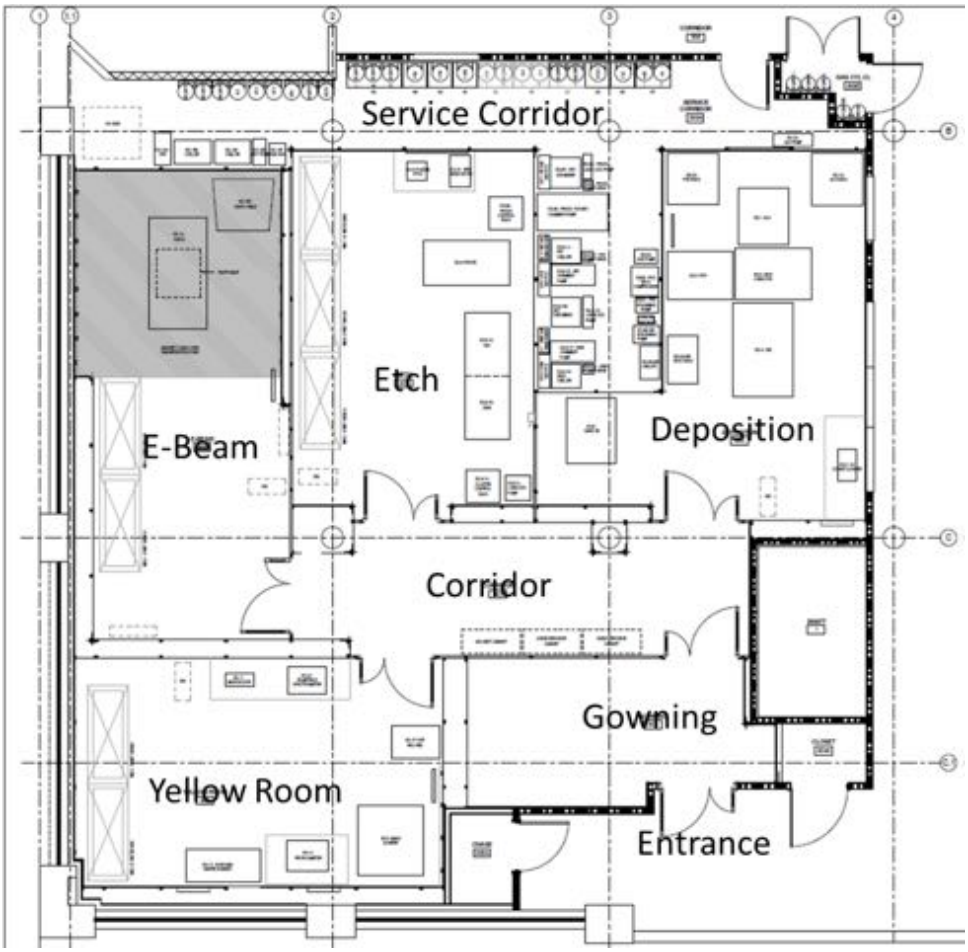

Figure 1: NanoFab Cleanroom Floor Plan.

The floor plan, as shown in Figure 1, shows seven main areas of the space. They are:

i. **Entrance/Gowning Area (Room 819A)**: Users will robe/disrobe within this area. In addition, storage space is available for users to store personal items which are not allowed inside the NanoFab space. This area is unsecured, so users are responsible for the safety of their items.
ii. **Corridor**: This corridor connects the four experimental bays of the NanoFab. Chemical cabinets for the appropriate storage are available for solvents, acids, and corrosives. Space is also available for storage of items which are permitted inside the space, such as tweezers, cleanroom notebooks, cleanroom pens and wafer carriers. A first aid kit will available in the corridor to allow access from all four experimental bays.
iii. **Deposition Room (Room 819D)**: The Atomic Layer Deposition (ALD), Physical Vapor Deposition (PVD), Ion Beam Etching (IBE) and Ultraviolet (UV) Ozone tools reside in this space.
iv. **Etch Room (Room 819D)**: Acid/Corrosive and Solvent wet benches reside in this space. An oxygen (O_2) plasma cleaning system is also located in this space. This space will be the future location of a Plasma Enhanced Chemical Vapor Deposition (PECVD) system, Deep Reactive Ion Etching/Inductively Coupled Plasma Reactive Ion Etching (DRIE/ICP RIE) Cluster Tool, and spin rinse dryer.
v. **Electron-Beam (E-Beam) Room (Room 819E)**: This space is dedicated to performing e-beam lithography. Inside resides a Raith 150^{Two} e-beam pattern generator, as well as wet benches for spin coating and developing e-beam resist.
vi. **Yellow Room (Room 819F)**: This space is dedicated to contact photolithography and metrology. A Süss MicroTec MA-6 Contact Aligner resides, as well as wet benches for spin coating and developing photoresist. Metrology tools also reside in this space, including a microscope and thin film thickness measurement instrument. This room is also the future location of a wafer bonding system and contact profilometer.
vii. **Service Corridor (Room 800S)**: Location of ancillary equipment. NanoFab users are not permitted access to this area.

2.7. Emergency Egress Procedures

In the event of emergency, all users are expected immediately suspend all work activities. Users are to exit the lab from the Gowning area. There are **NO other egress routes out of the NanoFab besides the Gowning area!** Users will be allowed to remove laboratory protective gear if time permits. Users can exit the building using the stairwell either on the NW corner of the building or the stairwell adjacent to the men's restroom on the 8th floor. These stairwells are shown in Figures 2 and 3. **ALL** users in the Cleanroom in the event of emergency evacuation must meet downstairs next to Dibner Hall, in order to be properly accounted for.

If equipment using toxic, flammable, or corrosive gases malfunctions due to gas leak, users in the vicinity of said equipment should do the following: (if the user is not in eminent danger)

i. Press the Emergency Off (EMO) button on malfunctioning piece of equipment
ii. Contact NYU Environmental Health and Safety at (212) 998-1450 (Do **NOT** call 911)
iii. Evacuate the building **immediately**

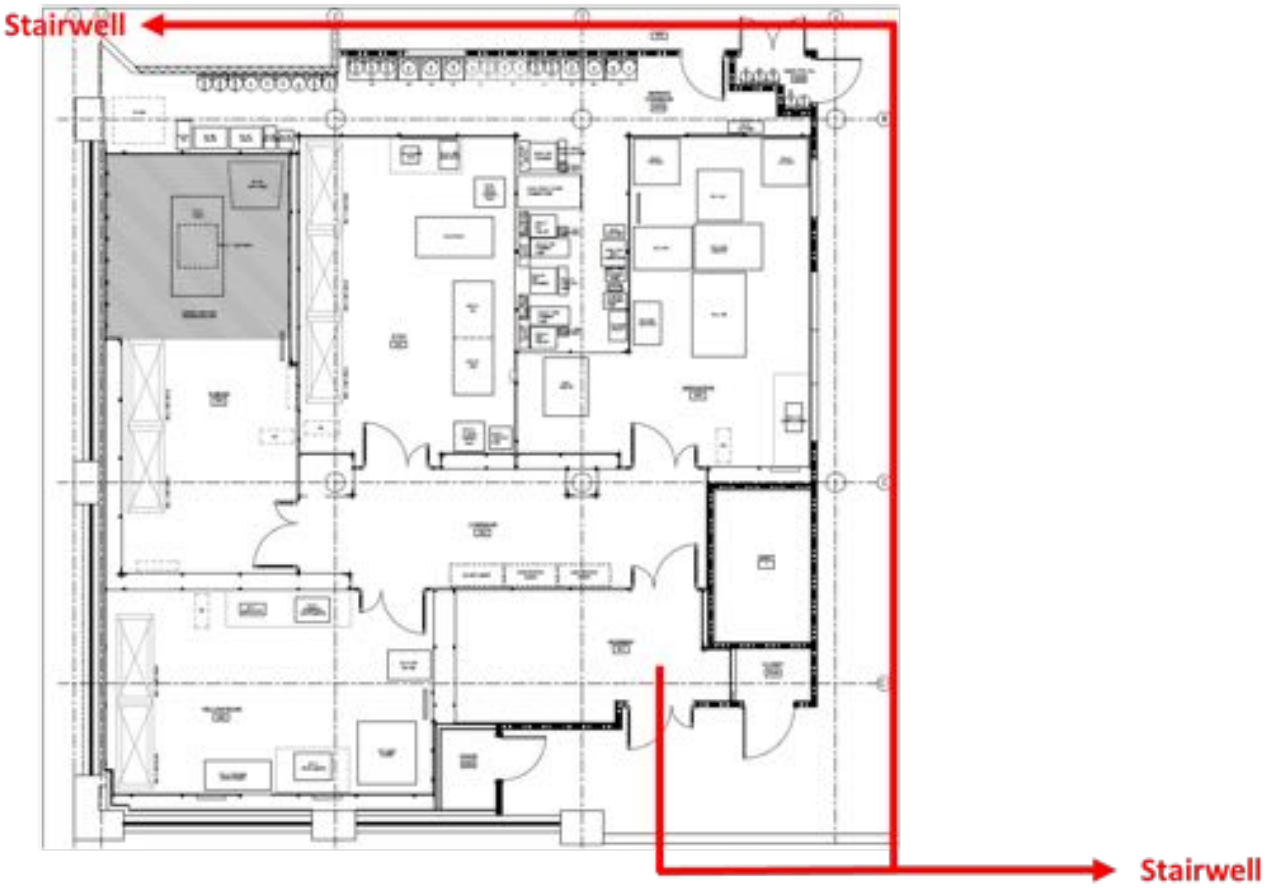

Figure 2: 8th floor Egress Routes

NYU NanoFab Cleanroom

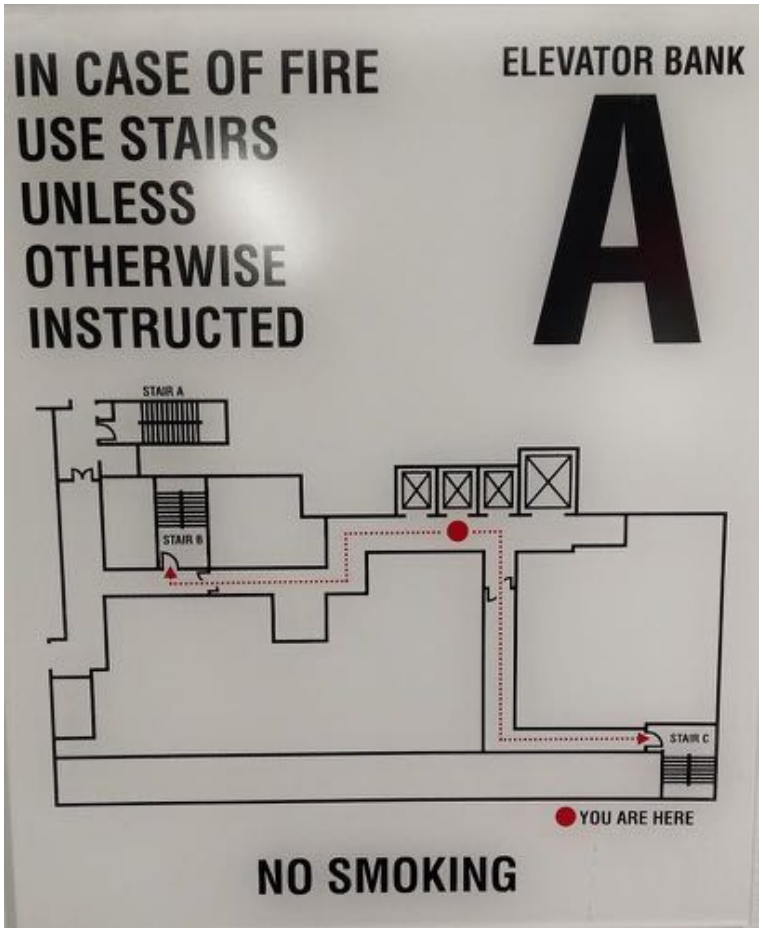

Figure 3: Elevator Bank and NanoFab location in relation to Emergency Egress Routes

3. Equipment Safety

All users must exercise caution when operating lab equipment. Users are strongly urged to use all equipment in accordance with operation instructions provided in the user's manual for a respective piece of equipment. Most of the equipment housed within the Cleanroom has electrical, mechanical, and radiation hazards associated with their use. Please **DO NOT** attempt to defeat or tamper with any safety interlocks. Please **DO NOT** attempt to make repairs or modifications to any piece of equipment. Instead, please notify the Cleanroom staff in the event of an equipment malfunction.

3.1. Electrical Hazards

Figure 4: Required signage communicating electrical hazard.

Cleanroom users must observe all warnings regarding electrical hazards as they relate to equipment and electrical panels. On most equipment, conspicuous labels such as the one shown above are used to indicate regions of equipment which may present an electrical hazard. Users are not allowed to open, inspect, or touch any item deemed to be an electrical hazard. Users are also not allowed to open service panels for any equipment in the Cleanroom. If an electrical safety hazard appears to exist, please notify the Cleanroom staff immediately.

3.2. Mechanical Hazards

Mechanical hazards can present themselves in various ways in the lab setting. Many of the pieces of equipment have pneumatically or electrically actuated transfer mechanisms, valves, lids, shutters, or other parts which execute either linear or rotational movement, or some combination thereof. Users must prevent contact with these items, as serious bodily injury can occur. Users must also avoid attempting to lift, move, or lean equipment on its side, as this can present a crushing hazard, which could cause serious bodily injury, or even death. Points of mechanical hazards for equipment are typically indicated by a label, as shown below.

Figure 5: [insert figure caption].

If any piece of equipment malfunctions and suddenly presents a mechanical hazard, please notify the Cleanroom staff immediately.

3.3. Radiation Hazards

Many types of the laboratory equipment housed in the NanoFab Cleanroom can generate electromagnetic energy, in the form of light and heat. In most cases, this energy is well contained within an enclosure to prevent accidental exposure. This energy can be generated by lasers, mercury (Hg) vapor lamps, and even hotplates. Exposure to certain wavelengths of electromagnetic radiation can cause severe eye and skin damage. Users must understand and obey all acceptable procedures when operating equipment that generates a sizeable amount of radiation, which includes contact aligners, plasma etch and deposition systems, UV ozone systems and hotplates. Users must also avoid staring directly into laser beams, regardless of the wavelength of the laser being used. Equipment that presents a radiation hazard usually has a label, such as the ones shown below.

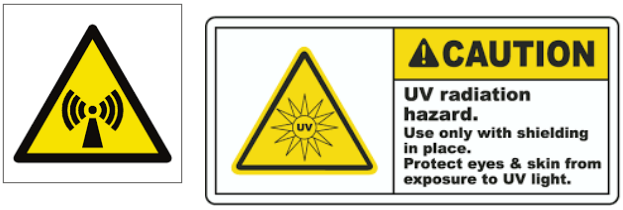

Figure 6 (a, b): insert figure caption

Users are also not permitted to defeat any interlock associated with any system which generates electromagnetic radiation. If a user suspects a malfunction of such equipment, please notify Cleanroom staff immediately.

4. Chemical Use and Safety Procedures

The Cleanroom is equipped for the storage and usage of different types of chemicals, including toxic, corrosive and flammable gases contained within pressurized cylinders, various acidic and basic liquids

and flammable solvents. Extreme care must be given in the handling, usage and storage of these items.

4.1. Acids

Acidic substances are mostly liquid in nature, which are characterized with having a pH of 6 or less. Acids will be mostly used in this laboratory for etching purposes. Examples of such substances are:

i. Chrome Etch (cerium ammonium nitrate, nitric acid, water)
ii. Aluminum Etch (nitric acid, acetic acid, phosphoric acid, water)
iii. Piranha Etch (sulfuric acid and hydrogen peroxide)
iv. Buffered Oxide Etch (ammonium fluoride and hydrofluoric acid)
v. Hydrofluoric Acid
vi. Nitric Acid
vii. Phosphoric Acid
viii. Sulfuric Acid

First aid response

Contact with acidic substances can result in the formation of chemical burns to the skin, as well as long-term damage to the affected area. As a rule, users will be required to wear protective gear at all times when handling and using these substances. This gear includes an acid-resistant apron, acid-proof gloves, face shielding, and protective sleeves covering the arms.

In case of accidental skin contact with HF, please follow the following procedure:

i. Rinse affected area with cool water for five (5) minutes
ii. Apply Calgonate gel, a 2.5% calcium gluconate gel that neutralizes hydrofluoric acid, to the affected areas and continuously massage into the skin
iii. Seek medical attention
iv. Reapply gel and massage into the affected area every 15 minutes until medical assistance is given

If acid splashes into the eyes, please perform the following procedures:

i. Flush eyes in eyewash station immediately
ii. Flush eyes with Calgonate Emergency Eyewash solution or at the emergency eyewash station
iii. Seek medical attention
iv. Continue to flush eyes with Calgonate eyewash or at eyewash station until medical assistance is given

Acids appropriate for use on Teflon and glass (or something similar)

The following substances should only be used in Teflon dishware:

i. Buffered Oxide Etch (ammonium fluoride, hydrogen fluoride, water)
ii. Hydrofluoric Acid

The following acids can be used in either Teflon or glass dishware:

i. Sulfuric Acid
ii. Nitric Acid
iii. Phosphoric Acid
iv. Chrome Etch
v. Aluminum Etch
vi. Piranha Etch

Chemical spill response

In the event of a spill, chemical spill kits will be available near the wet bench area in the Etch Room (Room 819D). Please notify the Cleanroom staff if such an event should occur.

4.2. Bases

Basic substances are mostly liquid in nature, which are characterized with a pH above 7. These substances can be used for etching as well as for development during photolithographic pattern creation, among other things. Examples of such substances are:

i. Hydrogen Peroxide
ii. Tetramethylammoniumhydroxide (TMAH) developer
iii. Metal-Ion Free (MIF) developer
iv. Potassium hydroxide (KOH)
v. Gold Etch (potassium iodide, KI)

Contact with some basic substances can result in the formation of chemical burns to the skin, as well as long term damage to the affected area. In addition, the prolonged inhalation of vapors from some basic substances can cause respiratory stress. It is required to use the appropriate Personal Protective Equipment (PPE), which includes a resistant apron, gloves, face shielding, and protective sleeves covering the arms when handling or using extremely caustic materials.

Chemical spill response

In the event of a spill, chemical spill kits will be available near the wet bench area in the Etch Room (Room 819D). Please notify the Cleanroom staff if such an event should occur.

In case of accidental skin contact, please follow the following procedure:

i. Remove any clothing obstructing the affected area and rinse with cool water for 15 minutes
ii. Seek medical attention if pain or irritation are felt.
iii. If the exposure is due to TMAH, seek medical attention even if pain or irritation are not felt

First aid response

If a basic solution splashes into the eyes, please perform the following procedures:

i. Flush eyes in eyewash station immediately for 15 minutes
ii. Seek medical attention

If an inhalation event occurs:

i. Relocate to a space with fresh air
ii. Seek medical attention

4.3. Gases

Different types of gases will be used to perform fabrication processes within the laboratory. Some are inert, while others can be toxic, flammable, or corrosive in nature. Other gases can become asphyxiants. The current list of available process gases is:

i. Ammonia (NH_3)
ii. Argon (Ar)
iii. Boron Trichloride (BCl_3)
iv. Carbon Dioxide (CO_2)
v. Chlorine (Cl_2)
vi. Helium (He)
vii. Hydrogen (H_2)
viii. Hydrogen Bromide (HBr)
ix. Nitrogen (N_2)
x. 1% Silane in Nitrogen (1% SiH_4 in N_2)
xi. Nitrous Oxide (N_2O)
xii. Methane (CH_4)
xiii. Octofluorocyclobutane (C_4F_8)
xiv. Oxygen (O_2)
xv. Sulfur Hexafluoride (SF_6)
xvi. Tetrafluoromethane (CF_4)
xvii. Trifluoromethane (CHF_3)
xviii. Xenon (Xe)

Regardless of the type, they all present a significant asphyxiation hazard, in addition to any other hazards they might pose, if released in an amount above a specific threshold, according to the type of gas. This happens when the oxygen level in the ambient air is 19% per unit volume or less. Some, but not all of the symptoms of an oxygen-deprived atmosphere are [1]:

i. Poor coordination and judgement
ii. Impaired thinking
iii. Reduced physical coordination
iv. Reduced physical stamina
v. Impaired respiration
vi. Nausea and vomiting

There also exists a frostbite risk when skin comes in contact with a rapidly expanding gas from a pressurized cylinder, so extreme care must be exercised when in the vicinity of such an occurrence, as in an emergency situation where there is a gas leak, for example.

All available gases to be used as part of NanoFab processes are located in the cleanroom service corridor (RH 800S). Access to this area is limited to **NanoFab staff only**. If a piece of equipment has been rendered inoperable due to process gas supply, please notify the NanoFab staff immediately.

4.4. Oxidizing Agents

Oxidizers increase the range of flammability for chemicals and speed up the development of a fire. Exhibit caution when working with an oxidizing agent to reduce the chance of a fire; keep oxidizers away from open flames or sources of ignition. Oxidizers can react aggressively if they come into contact with an incompatible material. When using oxidizers, use the minimum amount necessary, keep them away from any unknown materials and do not leave excess oxidizing agent in laboratory hoods when finished.

4.5. Chemical Storage Areas

Various locations within the lab are designated as chemical storage areas. The storage area, along with the type of chemicals allowed to be stored in a particular area, can be seen on the layout below:

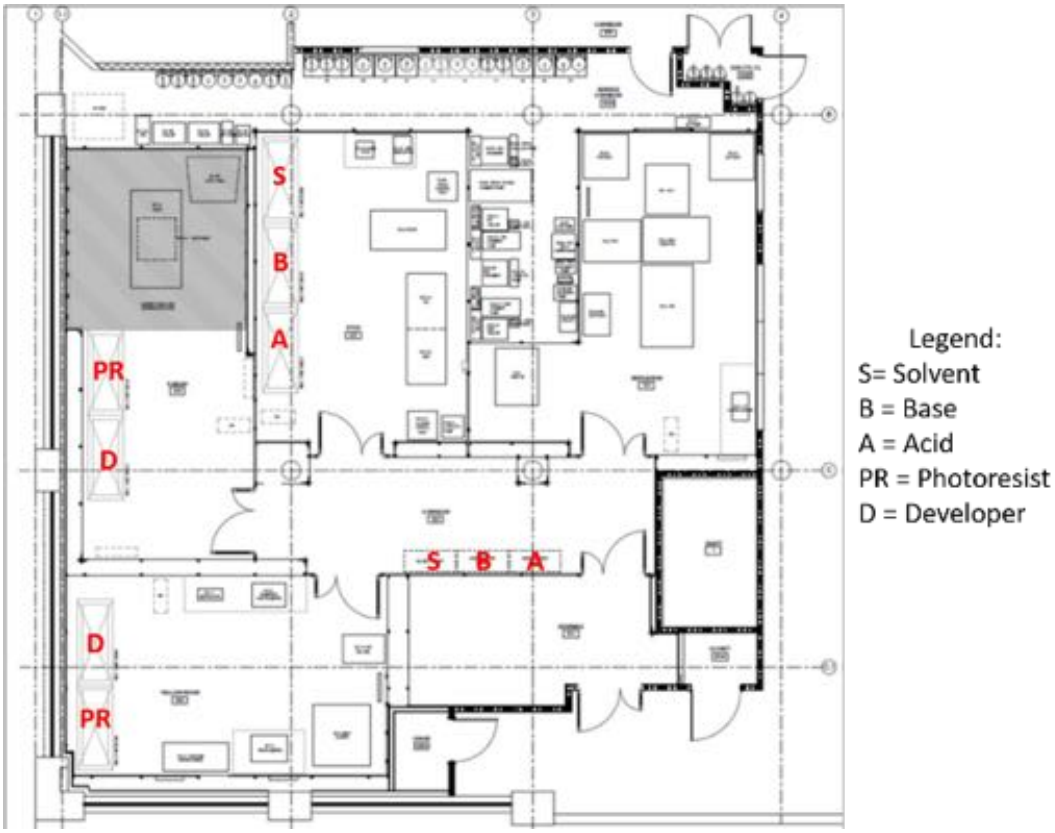

Figure 7: Chemical Storage Areas

As a lab user, it is very important to maintain as much separation as possible between the various types of chemicals, especially solvents and acids, for the combination tends to generate the formation of oxygen gas, which could be considered an explosion hazard under specific parameters.

4.6. Chemical Waste Disposal

The collection, storage, and disposal procedures developed in accordance with NYU EHS and FDNY guidelines are as follows for the different types of chemical wastes:

1. Solvents

1.1 If a used solvent does not originate from a fume hood, it should be containerized in a triple-washed polypropylene container. Four (4)-Liter containers are preferable. The container's original label markings should be crossed out with a Sharpie, and relabeled "Solvent Waste". All used solvents should be containerized in this manner, unless indicated otherwise. **DO NOT** overfill solvent containers. Once a container is full, please notify the NanoFab staff for removal and relocation of the waste container to a Satellite Accumulation Area (SAA).1.2 If a used solvent has been collected by a fume hood carboy and an alarm goes off, please notify the Nanofab

staff as soon as possible. Avoid using the fume hood until the carboy has been replaced. The carboy and/or its contents will be taken to a SAA for proper disposal.

2. Acids

2.1. Acids should not be poured down the drain. Used acids of different types should not be mixed together. Acids should also not be mixed with solvents or basic liquids. Used acids should be disposed in a triple-rinsed container where that original label has been scratched out with a Sharpie, and relabeled "Used Acid-Type", where "Type" indicates what type of acid will be poured into the container. When an acid container is full, users should notify the Nanofab staff so that the container can be relocated to a SAA.

2.2. If a carboy from an acid wet bench becomes full, notify the Nanofab staff immediately. Avoid using the wet bench until the carboy is replaced. The carboy will be relocated to a SAA for proper disposal.

3. Basic liquids

3.1. Basic liquids should not be poured down the drain. Used base liquids of different types should not be mixed together. Basic liquids should also not be mixed with solvents or acids. Used basic liquids should be disposed in a triple-rinsed container where that original label has been scratched out with a Sharpie, and relabeled "Used Base-Type", where "Type indicates what type of basic liquid will be poured into the container. When a basic liquid container is full, users should notify the Nanofab staff so that the container can be relocated to a SAA.

3.2. If a carboy from a base wet bench becomes full, notify the Nanofab staff immediately. Avoid using the wet bench until the carboy is replaced. The carboy will be relocated to a SAA for proper disposal.

4. Metal reclamation

4.1. Please notify the Nanofab staff in the event that used metals require disposal. Metals can be reclaimed from sputter targets, evaporation crucibles, and wafers with metals deposited onto them. The following procedures should be followed:

4.1.1. Sputter targets and evaporation boats and crucibles: notify the Nanofab staff for proper disposal

4.1.2. Wafers: for wafers with metals deposited onto them, dispose in the two (2)- gallon red sharps container labeled "for wafers with metals only". All other wafers should be disposed of in the two (2)-gallon red sharps container labelled "For wafers without metals only".

5. Other

5.1. Kimwipes, pipettes, etc. should be disposed of in the red fire-proof trash receptacles. Disposal can be arranged with NYU EHS when disposables are contaminated with hazardous substances.

5.2. Sharps (razors, x-acto blades, etc.) can be disposed of in the red sharps containers. Disposal of sharps will also be coordinated with NYU EHS.

5.3. Do not place solvent contaminated items in regular trash receptacle, place in red fire-proof trash receptacles

5. Conduct and Dress Code

5.1. Gowning Procedure

Users can gown and de-gown in the gowning area, room 819A. Shoe covers, gloves, beard covers, bouffant cap, goggles, and Tyvek suits will be provided by the Nanofab. Tyvek suits have an approximate one (1)-week lifetime, and each user will be assigned their own hanger to hang their suit during the week. After one week of usage, users are encouraged to gown in a new Tyvek garment. Beyond regular clothing, no other garments will be allowed inside the Nanofab. The gowning procedure is as follows:

a) Place shoe covers over shoes. Ensure that shoes do not have an abundance of dirt, grit, moisture, or mud on them prior to placing shoe covers on.
b) Put on beard cover (if applicable).
c) Place bouffant cap on head, ensuring that all loose hair is contained within the cap.
d) Gown in Tyvek suit by placing feet into the gray-colored recesses of the Tyvek garment. Insert arms into the upper portion of the suit.
e) Place hood of Tyvek garment on head.
f) Put on a pair of gloves.
g) Put on a pair of goggles.

The following items are not allowed to be worn inside the Nanofab:

a) Contact lenses
b) Makeup
c) Perfume or cologne
d) Lotion
e) High-heeled shoes (shoes worn must entirely enclose the top and bottom of the foot)
f) Skirts or shorts
g) Torn or soiled clothing
h) Open-toed shoes or flip-flops
i) Excessive amounts of jewelry

5.2. Allowed/Prohibited Items

The following items can be brought in and located inside the Nanofab by users for extended periods of time:

a) Cleanroom pens, paper, and notebooks
b) Wafers and wafer carriers
c) Tweezers
d) Flash or thumb drives

The following items are **NOT** allowed inside the Nanofab for any reason:

a) Portable audio/video players
b) Foreign,unknown or unapproved chemical substances
c) Gum, candy, sodas, or any other type of food
d) Laptops or tablets
e) Regular ball point pens and paper
f) Any other substance which may compromise the quality of the Nanofab environment

5.3 Code of Conduct

Nanofab users are expected to be considerate and gracious to each other while inside the Cleanroom. It is also expected that users will not perform actions which may bring physical harm to themselves, other users, or the Cleanroom. The following actions are **NOT** permitted inside the NanoFab, and such actions may warrant a suspension of user activity, leading up to total disbarment from the Cleanroom, depending on the nature and duration of the offense:

a) Running or horseplay
b) Communicating threats to other users
c) Throwing chemicals on other users, regardless of its nature
d) Fighting
e) Bringing chemicals inside of the NanoFab that are not approved by the staff
f) Bringing unauthorized users inside the NanoFab
g) Damaging the NanoFab equipment
h) Attempting to defeat equipment interlocks or operate disabled equipment
i) Attempting to repair NanoFab equipment
j) Viewing any offensive or pornographic materials on NanoFab computers
k) Mixing incompatible chemicals, which may cause fire, explosion, or liberate toxic fumes
l) Improper chemical storage
m) Neglecting to report chemical spills to NanoFab staff
n) Maintaining a sloppy and unkempt work environment
o) Overcrowding of available storage space
p) Using Laboratory phone for purposes other than contacting Nanofab or NYU staff/faculty
q) Any offense not listed which may disrupt the well-being of users or damage the Cleanroom and its equipment.

5.4 Clean Up

Users must maintain a clean environment inside the Nanofab. When finished, users must return any moved acids, bases or solvents to their original location. All equipment should be left clean.

Failure to follow the guidelines set by the Nanofab will result in suspension from the Cleanroom.

NYU NanoFab Cleanroom

Chemical Comaptibilty Matrix:

http://microsites.engineering.nyu.edu/nanofabrication/wp-admin/post.php?post=740&action=edit

6. References

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