



Cleanroom Safety Manual & Operating Procedures



**Nanoscale Research Facility
Indian Institute of Technology Delhi**



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Overview

This manual provides information about safety and operating procedure of NRF cleanroom facility. The procedures and protocols mentioned in the manual are required of any individual who works within the NRF cleanroom. This will protect not only the individual users but also the facility. This manual is divided into two separate sections.

The Ist section describes information about cleanroom training and certification procedure to be eligible to work at NRF cleanroom. It also describes what measures will be taken to ensure compliance with the protocols described in this manual.

The IInd section describes **SAFETY procedures and protocols**. It includes details about the do's and don't for the users in cases of emergency or accident. Safety procedures against chemical, fire, gases, cryogenics and others are discussed in the manual.

PART-1: Cleanroom Training and Certification

All the users of NRF cleanroom facility must undergo cleanroom comprehensive training which involves lectures as well as demonstration. The following steps are needed to become a certified cleanroom user.

1. Cleanroom training on Safety and Operating procedures

NRF cleanroom training will be given on a monthly basis to new users of the facility by the cleanroom manager and NRF staff by a lecture course. This training will provide new users information about the NRF cleanroom requirements for safety considerations, standards of cleanliness, and type of equipment available at cleanroom. At the end of the lecture course there will be a TEST on Safety and Operating procedures for cleanroom. This is mandatory for all users of the cleanroom. 80 marks out of 100 are required to pass this TEST.

2. The users who pass the TEST will be given a cleanroom tour by NRF staff to make them understand about the cleanroom procedures. All persons working in the NRF cleanroom must obtain safety & training certification from the NRF cleanroom manager. After successful completion of cleanroom training user will get himself registered at NRF office for biometric access to the facility. This safety training is considered a minimum for entry into the NRF cleanroom facility, but does not constitute training for equipment usage.

3. Training on Cleanroom Equipment

To obtain training to operate equipment in the clean room the user must first get cleanroom certification. The training for specific process operations will be provided by an experienced operator if needed.

4. Violations of Safety, behavior, or cleanliness policies

Persons not abiding by the policies and procedures of NRF cleanroom may present a significant hazard to both the other users and the NRF cleanroom facility. It should be clear that any violation of these standards for safety and operating procedures is inexcusable and the offender can be disciplined by NRF management. In addition, all personal behavior is expected to be professional within the lab. Any form of inappropriate personal behavior must be reported and corrected. Such behavior will be met with disciplinary measures appropriate to the violation. If needed NRF management can revoke access of violator to all the cleanroom facility for a specified period of time.

PART-II: Safety Manual

The prime concern is for the safety of all personnel.

- a) In case of **Emergency** call at IIT Delhi security immediately at xxxx
- b) Notify NRF cleanroom manager/staff on xxxx.
- c) Evacuate the dangerous areas. Keep in mind that the recirculation of cleanroom air can quickly spread dangerous vapors throughout the entire cleanroom.
- d) **Warn others.** If you must evacuate, make sure that others are notified and comply with the evacuation.
- e) Subsequent cleanroom re-entry will be authorized by cleanroom manager/Staff.

In case of **Fire Alarm** sounds, **evacuate the cleanroom as quickly and as safely possible.** Do NOT remove your clean room clothes; **immediately exit.**

Access to the Cleanroom

Access to the cleanroom is a revocable privilege, and is available only during the hours published by the NRF cleanroom management. External users, such as other educational institutions may be granted access to the NRF cleanroom in accordance with approved agreements by the NRF management.

Safety Equipment

All users must know how to use the following safety equipment and their locations.

- i. Phone: There are xxx phones in the cleanroom. Location xxxx

ii. First Aid Kit: The First Aid Kit is located on both floors of cleanroom in the gowning rooms.

iii. Fire Extinguishers: There are fire extinguishers located at xxxx

iv. Fire blanket: The fire blanket is available in the gowning room entry on both floors of cleanroom and labelled “**Fire Blanket**”. Wrap a burning victim in this blanket securely to put out the flames – call for help.

v. Showers and Eye Wash Stations: There are **shower/eyewash stations** located at the corridor of the cleanroom (see the cleanroom layout).

If there is a **Chemical Spills** on your clothes/body, use the shower. Immediately begin flushing with plenty of water and continue to flush for at least 15 minutes. While showering, remove your affected clothing so as to remove the source of chemical danger from yourself. A spare blue smock is hung next to each shower for cover after the shower. Do not put contaminated clothing back on after rinsing. Call for appropriate medical assistance as soon as possible.

If there is a **Chemical Splashes** into your eyes, use the eyewash stations located at the corridor of the cleanroom. Let the water flow over your closed eyes for a few moments before beginning to open them. This will make sure that the water is clear and pure. Wash out your eyes with water for at least 15 minutes after opening them. If you have splashed chemicals both in your eyes and on your body, then you may want to use the shower first and rinse your eyes in the shower. After showering, rinse your eyes using the eyewash station as well. Remove any affected clothing while rinsing your eyes at the eyewash station so as to remove the source of chemical danger from yourself. Call for appropriate medical assistance as soon as possible.

Chemical spill Clean-up

You need to notify Cleanroom manager/staff immediately of the spill. There are chemical spill absorbing compounds located at each Fume hood in the

cleanroom. Note that there are jars for neutralizer granules for acids, bases, and absorber granules for solvent spills. The general application method is to pour a ring around the spill to initially contain it and then fill in the ring to complete the absorption and containment.

HF Exposure treatments

In case of exposure of HF to skin use Calcium gluconate gel cream available near the acid hood in a tube form. Familiarize with its location. Apply the gel all around the exposure in lavish amounts immediately. **The exposure must be reported to the Cleanroom manager/staff.**

Calcium gluconate provides extra calcium ions which can bind-up free fluorine ions before they penetrate your body and cause damage.

Safety against Chemicals

It is very important to always know the properties of the chemicals you are using in the cleanroom. Broadly, chemicals fall into a few classes: Water, Cyanides, Solvents, Acids and Bases. Other descriptors are often used to describe chemicals as well. These include “toxic,” “flammable,” “combustible,” “cryogenic” and the state of the chemical (solid, liquid or gas). These classes and descriptors may not cover all possible chemical properties, but are nearly always used to characterize our chemicals. The properties of every chemical you use in the lab can be discovered by examining its **Material Safety Data Sheet (MSDS)**. You must be familiar with the MSDS information before using any chemical. **All chemicals must be physically transferred into the clean room facility by Cleanroom staff.**

MSDS information is located on the table just inside the clean room gowning room.

De-ionized Water: De-ionized water is provided for fabrication process purposes only. This is not considered potable water and must not be ingested.

Cyanides: Cyanides are generally highly toxic compounds that can release a highly toxic gas (for example, Hydrogen Cyanide, HCN) if they come into contact with an acid. Use of these materials is RESTRICTED.

Solvents, Acids and Bases: Solvents may only be used in the solvent hoods. An inventory of typical ULSI grade solvents is located near the fume hood. They are often very volatile - (they evaporate very quickly and therefore could get into your lungs and poison you) - many are known carcinogens, and many are flammable or combustible. Examples include: Acetone, Isopropyl Alcohol, Ethyl Alcohol, Methyl Alcohol, Methylene Chloride and Benzene. Clearance for all solvents must be secured from Cleanroom management prior to their introduction into the clean room. Note that in general solvents target the central nervous system.

Acids may only be used in the acid fume hoods and a supply of typical etchants is provided as standard stock by the clean room. Acids can cause severe body damage on contact: they can chemically burn the body, they can be toxic, they can cause rapid heating through exothermic reactions (and thermally burn the body) and they can even initiate explosions. Examples include: HF, HCl, H₂SO₄, HNO₃, NH₄F, etc. Note that some acids require special precautions. Clearance for all etchants must be secured from Cleanroom management prior to their introduction into the cleanroom.

Bases can only be used in an approved hood. They can cause severe burns, severe irritation, pain, nausea, vomiting, diarrhoea, deep skin ulcers, coughing, breathing difficulty, shock, blindness, possibly even coma and death. Examples of bases include: KOH, NaOH, NH₄OH, and Photoresist Developers. Clearance for all

Bases must be secured from Cleanroom management prior to their introduction into the clean room.

Hydrofluoric Acid (HF) HAZARD

Concentrated HF is considered “extremely” toxic. It gets 4 on the health hazard scale of 0-4. This is because it is a source of free fluorine ions. Any solution containing a source of free fluorine ions is also hazardous to your health. A concentrated ammonium fluoride solution is “very” toxic (3 on the health hazard scale) and becomes “extremely” toxic when made more acidic, such as in Buffered Oxide Etch (BOE) mixtures.

On contact, fluorine ions (from the HF) easily pass through skin and tissue. Because HF’s action can be delayed for many hours, it can distribute throughout your body. The negatively charged fluorine ions bind very easily and tightly to positively charged calcium and magnesium ions to form insoluble salts (CaF_2 and MgF_2 salts form some natural gemstones). In the body, Ca and Mg ions mediate a variety of physiological processes such as muscle movement and body chemistry. Calcium is also a chief component in bone. The result can be several severe forms of damage to your body and even death. Local tissue damage (at the point of contact) results from free hydrogen ions which cause corrosive chemical burns and free fluorine ions which cause deep tissue damage including erosion of your bones.

Systemic conditions include hypocalcemia (loss of calcium) and hyperkalemia (too much potassium). Since calcium and potassium regulate the beating of your heart, an irregular heartbeat and cardiac arrest can result. “Deaths have been reported from concentrated acid burns to as little as 2.5% of body surface exposed to skin contact.” That is the equivalent of a single hand.

Even dilute HF must be treated with extreme caution. It is highly dangerous to your body because it can poison you without your knowledge. Dilute HF may not cause a visible and painful skin burn (or tissue burn), and you can be fooled because you do not feel any pain. Even so, the fluorine ions can soak through the skin and upset your body's Ca and K balance as well as etch away your bones. The result may only become extremely painful hours after the exposure.

Calcium gluconate gel cream (sometimes called "HF antidote") is available near the acid hood in a tube form. Familiarize yourself with the location of this tube of gel. It can be applied to your skin and must always be available and within reach whenever HF is used. Apply the gel all around and over the exposure in lavish amounts immediately. **The exposure must be reported to the Cleanroom staff/management.**

Note also that Hydrogen Fluoride gas is extremely toxic as well. It very easily dissolves in water to become Hydrofluoric Acid. Gaseous HF can easily become liquid and liquid HF can easily become a vapor. If you breathe these fumes, you are bringing HF into your lungs where it is rapidly absorbed by the blood stream and distributed throughout your body. Therefore, HF containing chemical containers may only be opened and used in an appropriately vented Acid hood with all required safety gear.

Flammable/Combustible and Toxic Chemicals

Users must obtain approval **prior** to introduction into the clean room for any flammable or combustible chemicals from the Cleanroom management. Many chemicals are toxic in one form or another. See the MSDS sheet for appropriate safety precautions and then follow those precautions. Users must obtain approval from the Cleanroom management **prior** to introduction into the cleanroom for any toxic chemicals.

Photoresist and Developers

Most of the photoresists are mixture of solvents, resins and photo-active compounds. The resulting chemical can be toxic, flammable and/or irritating. Use these chemicals only in approved ventilated areas, such as solvent hoods or photoresist spinners. As a reminder, do not breathe the vapors given off by photoresist as it bakes on a hotplate. Utilize the “hooded” hotplates.

Use of Cryogenics (such as Liquid Nitrogen)

Liquid nitrogen (LN₂) present a safety hazard due to their extreme cold. Users should be familiar with this hazard and use appropriate cryogen gloves as well as designated personal protective equipment against the freezing effects. Under no circumstances should a user allow to contact LN₂ with their body. Severe injury can result from such contact. Cryogenics can displace the oxygen in the air your body needs to live as they evaporate. Therefore you must only use liquid nitrogen in well-ventilated rooms. Users should make arrangements of LN₂ in advance for their needs and ask for the help of Cleanroom staff.

Waste Disposal

Never pour solvents down the water sink drain! The NRF Cleanroom has clearly identified waste streams for solvents, acids, caustics, sharps, and other

associated trash. There are waste containers under the hood deck that are properly exhausted.

Unknown Materials and Chemicals

NEVER use unknown/unlabelled chemicals. Report any unlabelled chemicals to Cleanroom staff immediately. **All chemicals should be both labelled and dated at all times.** The label should describe the chemical in the container (beaker, flask, bottle, etc.), have an expiration date, the owner contact information, and date.

Compressed Gases

Compressed gas cylinders present a significant safety hazard to lab personnel. A broken off valve can cause high-pressure gas to launch the cylinder causing great physical danger and damage. Leaks hooking up the cylinder to system lines can cause chemical injury to lungs, fire hazards, etc. **Only Cleanroom staff or personnel authorized by Cleanroom management are allowed to change, replace, or otherwise handle compressed gas.** Cylinders are to be properly anchored. There are Toxic gas monitors for safety. Only authorized personnel may handle these systems.

General Safety Guidelines

1. When in doubt, ask questions of experienced personnel before taking any action.
3. Always clean up after yourself and clean the aisles of chairs and other obstructions.
4. Do not work in the Cleanroom if you feel particularly tired or unwell.
5. For safety reasons, do not sit on worktables or lean on benches or equipment.
6. Contact lenses are not allowed when using chemicals, since vapors can be drawn under the lenses by absorption and capillary action and concentrated there. Wear prescription glasses and safety glasses instead.
7. When pouring or refilling liquid N₂, proper goggles and insulating gloves are required.
8. Always wear complete safety apparel when handling chemicals and follow all safety instructions. An acid proof apron, face shield, and acid gloves are required when using acids.
9. Do not touch your face, nose, mouth, etc. when wearing acid gloves. Skin damage can result from glove contamination. In addition, skin oils can spoil processes and contaminate samples by transfer from face to glove to sample.
10. Do not leave hazardous equipment/materials unattended when in use (e.g. chemicals on hotplates, liquids in beakers in hoods, etc.) Before starting an experiment, the user must label the containers for his process with all of the following information:
 - i. User name
 - ii. User's cell phone number (required)
 - iii. A complete list of all the chemicals being used or equipment process parameters
 - iv. The date/time the user initiated use of the chemicals

11. The following chemical types must be stored in separate storage cabinets and properly labelled: a) acids, b) solvents, and c) bases. Do not place chemicals in the wrong cabinet.
12. When mixing etches, always add acid to water. Never add water to acid. **If you add water to acid, exothermal mixing energy can cause the water to rapidly heat to the boiling point and splatter a mixture of water and acid.**
14. Before removing acid gloves, rinse well with water at a sink to remove any remaining acid. Do not allow water to get inside gloves.
15. Wear goggles and insulating gloves when pouring liquid N₂.
16. Rinse empty chemical bottles three times with DI water and label “rinsed.”

NRF Cleanroom General Rules:

1. No food or drink may be brought into any area of the Cleanroom.
2. Regularly wipe down tables and equipment surfaces with DI water and Cleanroom lint-free towels. Follow your schedule posted by the Cleanroom staff.
3. Always clean up after yourself.
4. No personal items (such as backpacks, makeup, combs, brushes, handkerchiefs, etc.) may be brought into the Cleanroom or the gowning area.
5. No paper should enter the Cleanroom unless it is certified lint-free by cleanroom staff.
6. No spray cans or powdered materials are allowed in the cleanroom or gowning area.
7. No cardboard boxes or packages are to be brought into the Cleanroom.
8. Shoes should be clean and free from dried mud, dirt, etc. Put your shoes into the steel shoe rack in the cleanroom corridor and put on cleanroom slippers before walking over the tacky mat.
9. Make sure the tacky mat is clean before stepping on it. Remove heavily soiled tacky mats prior to stepping on them. Dirty mats are a contaminant source.
10. Cleanroom garments are only to be worn inside the Cleanroom areas.

Cleanroom Gowning

The primary reason for gowning in cleanroom before entering the facility is to maintain the cleanliness of the facility. Humans are major sources of both contaminants and particulates (dust). The contamination of the facility by exposure to human skin, hair and street clothes must be minimized to promote a reasonable research environment. People shed both particles and chemical contaminants (skin oils, sodium, saliva etc.) that can destroy the ability of researchers to fabricate good devices if not properly contained.

Correct way to wear cleanroom gown

Everyone entering the Cleanroom must properly dress in the gowning area before entering. The correct gowning order is as follows:

1. Enter the clean room lobby and walk on the sticky mat.
2. Put on clean shoe covers at the entry bench. Check the booties for holes or cuts and discard bad booties.
3. Put on a Hair net ensuring that all hair is contained.
4. Put on the jump suit.
5. Put on clean room gloves (no powder gloves) folded over the sleeves of the coverall.

The garments are removed in the reverse order when leaving the clean room.



Eyes Protection and additional protective Wear

Everyone in the Cleanroom is required to wear approved eye protection. Contact lenses do not provide adequate eye protection and in fact can be hazardous in the presence of chemical vapors. Therefore, contact lenses are not allowed in the

Cleanroom. Safety glasses must be worn over corrective glasses and are available in the gowning area. Please return your safety glasses to the rack when exiting. Persons performing specific chemical processes, such as working with acids, must wear additional designated personal protective equipment. This includes the use of appropriate gloves, face guards, and chemical aprons for protection against spills or splashes. Additionally, workers in the clean room are required to use latex gloves during ordinary handling of their specimens and equipment, to avoid contact with skin. These gloves should be considered contaminated when leaving and must be discarded before exiting the clean room. Office doors or other outside items should not be handled while wearing these gloves, for both your own safety and that of colleagues or visitors to your office areas.

Cleanroom Visitors

An authorized Cleanroom personnel must be present to escort a visitor to the Cleanroom. The escort will be held responsible for the safety of his/her visitor. All visitors must be properly gowned. There are separate cleanroom garments for visitors. Visitors are not allowed to operate any equipment in Cleanroom.

Specific Guidelines inside Cleanroom

1. Before operating any equipment you need to sign-in to its logbook.
2. Always clean up after yourself as soon as you have finished a process or using a tool.
3. Note any tool/equipment malfunctions in the associated logbook.
4. Assume the responsibility for a neat, clean and safe work area.
5. Do not operate equipment until first trained by cleanroom staff.
6. Touching any surface in the Cleanroom requires wearing appropriate gloves.

7. All materials, samples, etc. that are not in the process of being worked on must be stored in a designated covered box. Chemicals will **NOT** be stored in such boxes.
8. All beakers, graduated cylinders, etc., should be emptied, rinsed and dried at the end of their use and stored properly. Rinse out empty chemical bottles (three times minimum) and label “rinsed”.
9. Do not leave hazardous equipment/materials unattended when in use (e.g. chemicals on hotplates, etc.).
10. Gloves, aprons, safety glasses or face shields are not to be left laying on the worktables or equipment. Return them to their storage locations.
11. Do not touch your face when wearing plastic or rubber gloves.
12. Do not taste, smell or touch any chemical, vapor or gas.
13. Never mix acids and solvents. Keep all solvents away from acid areas and vice-versa. Do not store them together. Use the correct chemical hood for each process.
14. Never store a chemical container on the floor.
15. Small amounts of solvents for individual use may be kept inside appropriately labelled squeeze bottles and stored in the solvent hoods.
16. Use chemicals in well-ventilated chemical hoods.
17. Dispose of wipes in properly labelled waste cans.
18. Do not use unlabelled chemicals.
19. Broken wafers and glassware are disposed of in a “sharps” trash-container and not in the regular trash bin. Make certain the sharps are free of chemicals before disposal.
20. If you break a wafer or piece of glass, the affected area must also be vacuumed to remove the particles – contact the Cleanroom Staff for assistance.

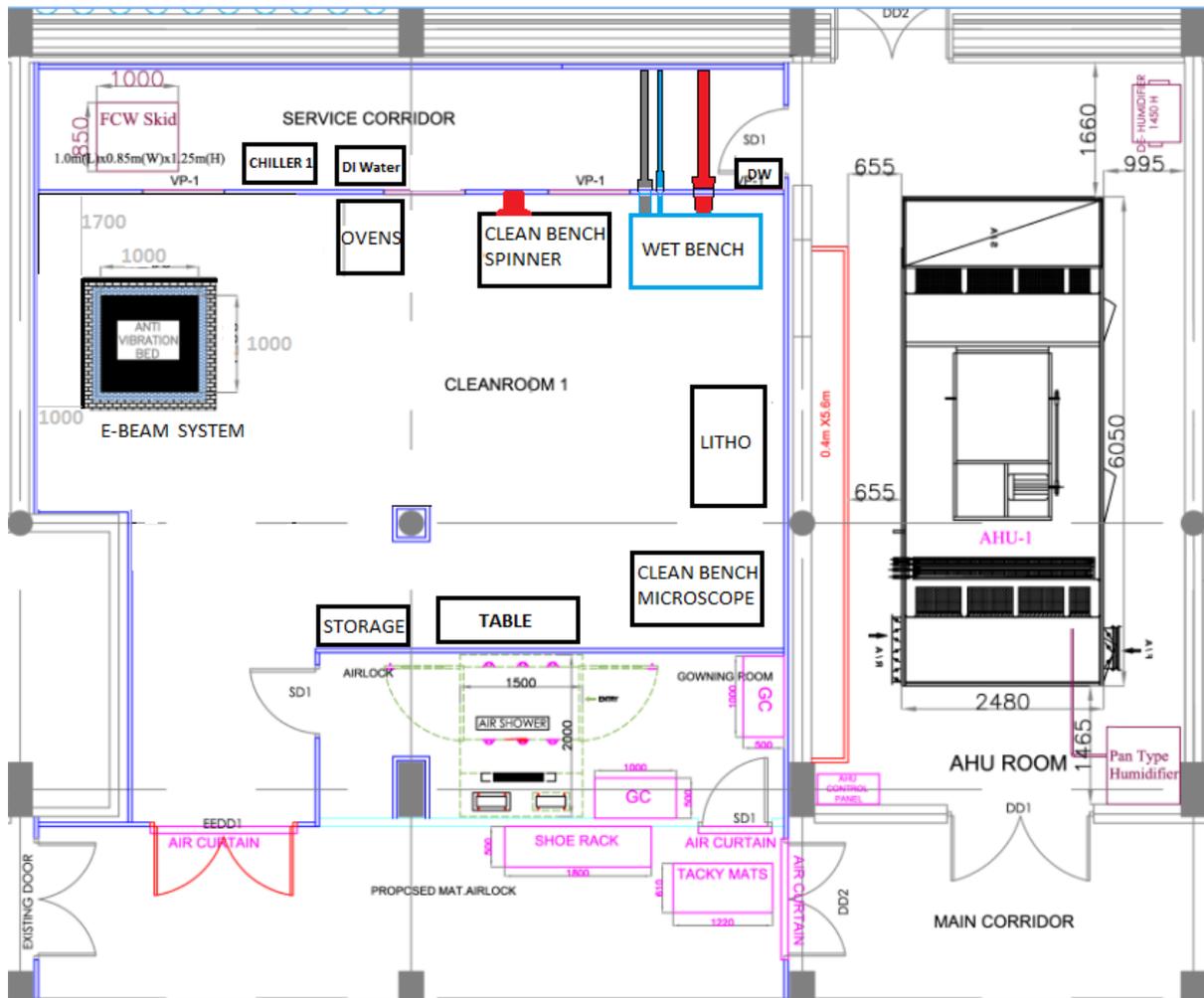
Chemical Inventory & Use of New Chemicals

All chemicals used in the Cleanroom facility must be approved by the NRF Cleanroom management and inventoried. **Chemicals cannot be brought into the Cleanroom facility by users without the explicit approval of the NRF Cleanroom manager.** Users requiring fresh chemicals which have been depleted in the Cleanroom stock must contact the Cleanroom Staff, who will transport those chemicals safely to the Cleanroom facility for users.

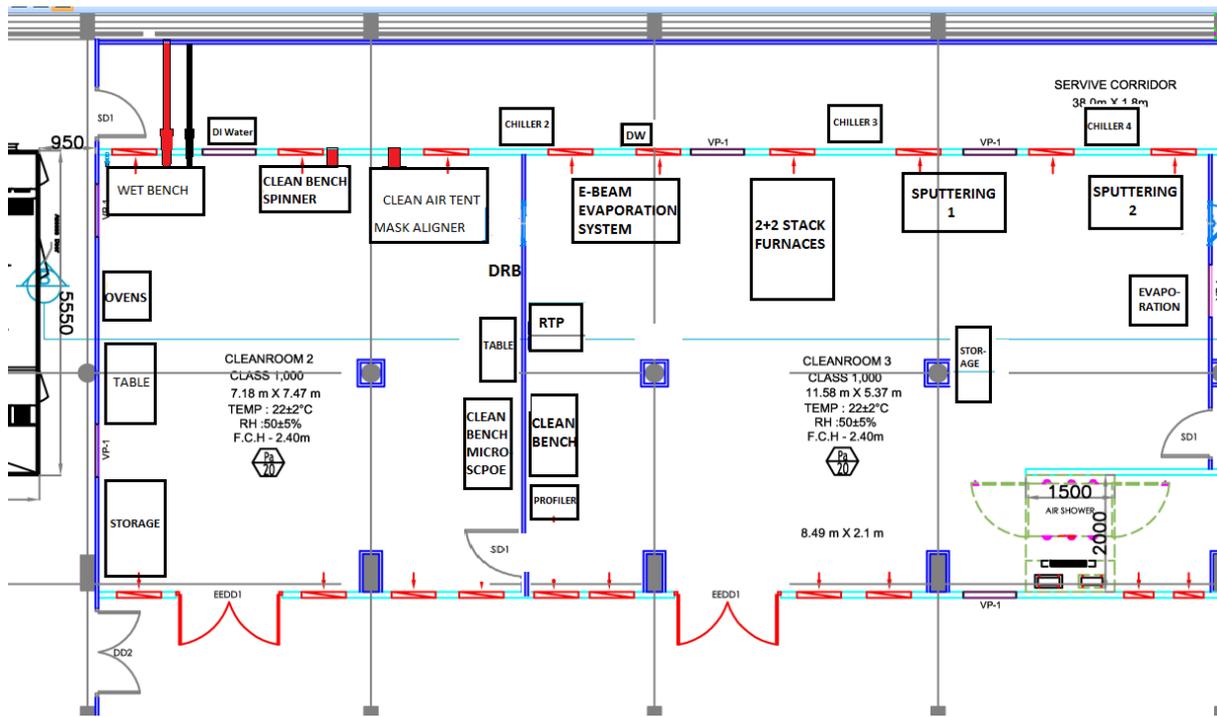
All users are required to follow all established procedures for proper handling of any chemical that they use in the clean room. Users are responsible for the development of specific chemical processes and recipes for their own needs. Training on these recipes is the responsibility of the user, and details on the training must be provided to the Cleanroom manager/staff. General safety practices associated with the usage, storage and handling of specific chemical is provided during the certification process, but this training is no substitute for the detailed safety training required for user-specific recipes.

Introduction of any new chemical into NRF Cleanroom without the permission of the Cleanroom manager/staff is prohibited. Proposals must be provided sufficiently in advance to the Cleanroom management so that its safety and compatibility with other aspects of the lab can be managed and supported in a safe and clean manner. MSDS sheets for the proposed chemicals must be included as part of the request. Final decisions on the appropriateness of such new introductions to the Cleanroom rest with the NRF Cleanroom management. **All chemicals must be transferred into the clean room by Cleanroom staff – no exceptions.**

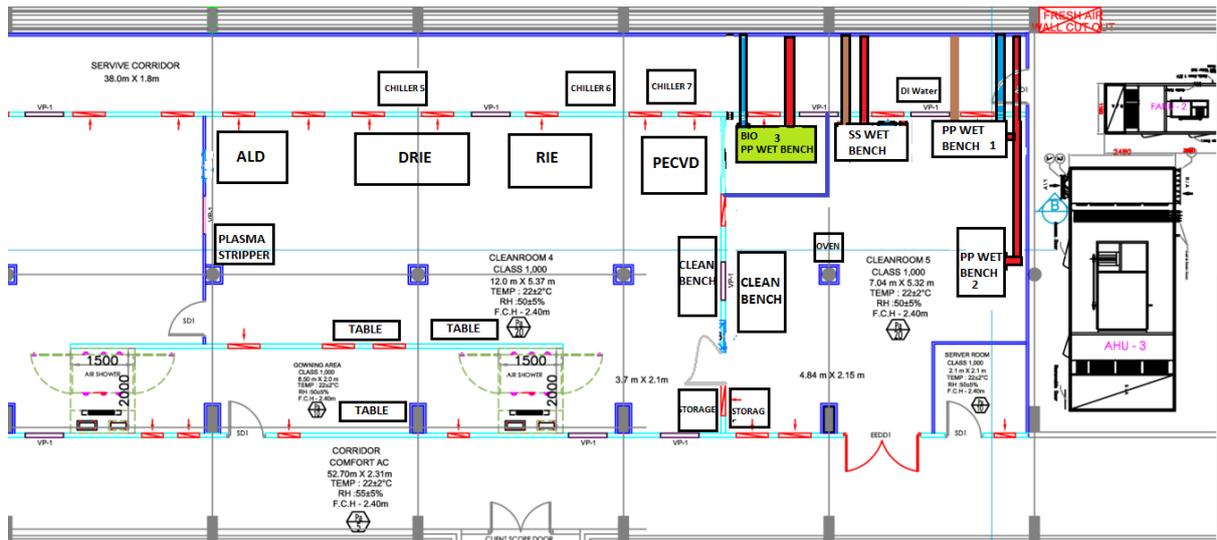
LAY OUT PLAN OF NRF CLEANROOM (GROUND FLOOR AND 1ST FLOOR)



CLEANROOM -1 GROUND FLOOR



CLEANROOM 2&3 FIRST FLOOR



CLEANROOM 4&5 FIRST FLOOR

Emergency Evacuation Route

Items not allowed in the clean room area:

- Regular paper, wood based paper products
- Laptop Computers
- Chewing gum or Tobacco products
- Facial make up
- Lab tissues, tissues, cardboard, books, and magazines.
- Styrofoam products.
- Powders
- Erasers, pencils, felt-tipped pens (other than Sharpie markers).
- Anything that can easily shed particles or aerosolizes; i.e., anything that may serve as a source of particles.

Acceptable Clean room items:

- Clean room notebooks and clean room paper. Single sheet clean room paper is provided.
- Your samples and tweezers, in clearly labelled small boxes.
- Pens (preferably, ball-point).
- Materials with smooth, hard surfaces such as plastic, which can be easily cleaned with moist wipes.

