Laboratory Manual Part II:
Laboratory Safety

Dec. 2, 2015

Table of Contents

1. Safety Philosophy

The goal of safety is to prevent accidents. This is best achieved if every person in the lab: 1. understands safety hazards, and 2. observes safety precautions. However, no system is perfect, and accidents will happen. Thus, our objective is also to mitigate accidents by educating you on how to respond in an emergency.

1.1 SNF Responsibility

SNF's responsibility for laboratory safety is to:

1. educate and inform labmembers of safety hazards and response procedures in the lab; and
2. provide the tools and resources to use the lab safely.

Safety hazards are communicated through:

1. this Safety Training Class;
2. the SNF lab wiki;
3. Stanford Environmental, Health, and Safety organization; and
3. training for each individual tool in the lab.

The tools and resources provided by SNF include, but are not limited to: the MSDS information for chemicals used in the lab; operating procedures and training in safe operation for each tool; personal protective equipment (PPE) and training in its use; documented procedures for actions to take in an emergency situation; knowledgeable personnel, trained in safety and emergency procedures.

1.2 Labmember Responsibility

As an SNF labmember, your responsibility is to behave in a safe, conscientious, and professional manner in all lab activities. The SNF provides you with information and tools to use the lab safely; however, each individual takes responsibility for his/her own personal safety. Moreover, as the SNF is a shared lab, each labmember is responsible for the safety of fellow labmembers. Anyone found behaving irresponsibly to the extent of endangering themselves or others may lose access to the lab, at the discretion of the SNF staff.

The staff also recognizes that in this research environment labmembers need to test and develop new tools and process capabilities. The labmember's responsibility, in these cases, is to work with staff to ensure that any new procedure/chemical/equipment introduced in a safe manner.

It is also your responsibility to report any safety concerns you may have to each other and to SNF staff. To report any potentially unsafe conditions or practices, or to offer suggestions for improving safety, direct an email to safety@snf.stanford.edu.

2. General Safety

2.1 Lab Behavior

As in any area in which chemicals are used, eating and gum chewing are prohibited. Water bottles are prohibited. Drinking is allowed only at the water dispenser in the service area.

In the lab, avoid sudden and fast movements (i.e., no running). Avoid collisions with others by approaching corners and turns slowly. Remember those around you may be handling sensitive materials (such as chemicals, or precious devices.)

Minimize clutter; clean up after yourself -- remove or store everything brought into the lab. Label all personal belongings so that they may be returned if misplaced. Always be aware of your work area and be sensitive to what others are doing around you.

2.2 Clothing

Shoes must fully enclose feet (no sandals, open toe, or sling-back shoes). Since you will be wearing a bunnysuit over your normal clothing, your clothes should be light, comfortable and allow free movement. Bare legs (i.e., wearing shorts and dresses) are not recommended; slacks are preferred as they provide additional protection to legs.

2.3 Eye Protection

Eye protection in the form of safety glasses or goggles should be worn at all times in the lab. The exception is when using a microscope or equipment with eye pieces. Eye protection must conform to ANSI standard (marked "Z87".) For labmembers requiring corrective lenses, impact-resistant prescription safety glasses with side shields may be purchased from most prescription glasses suppliers. Contact lenses are allowed, but safety glasses are still required for normal lab activities. Contact lenses are not allowed when full-face respirators or SCBA's are used (applicable to staff only.) Most safety glasses are designed to protect only against flying fragments, however, not chemical splash hazards. So full face shields should be worn in addition to glasses when handling chemicals or working at chemical wet benches.

2.4 Protective Equipment

While operating certain stations, Personal Protective Equipment (PPE) will be required. Use of any wet benches or the normal handling or transportation of any chemicals in the lab requires the use of PPE. See the chemical handling procedures in the appendices for specific details.

2.5 Buddy System

For safety reasons, no one is allowed to work in the lab alone at any time. Because the lab runs 24/7, there may be occasions (such as a late night, over a long holiday weekend) when there are no other people working in the lab. If you plan to work during a time when the lab might be expected to be empty, please plan ahead and coordinate your work schedule with another labmember. This way, you can be sure to have a buddy and can work safely.

2.6 Special Health Considerations

Pacemakers: Equipment in the lab may serve as sources of high voltage, ionizing radiation, ultrasonic interference or electromagnetic interference, which may affect normal operation of a pacemaker. If you have such a device, you should consult your physician before working in the lab.

Pregnancy: Labmembers who are pregnant or contemplating pregnancy should be aware of hazards in the lab, particularly volatile organic compounds (VOC's). Labmembers who are concerned should discuss with their supervisors and the SNF Safety Officer.

Chemical and Latex Allergies: Certain chemical compounds may trigger allergies in sensitive individuals. One common sensitivity is to latex, found in the cleanroom gloves. Vinyl and nitrile cleanroom gloves are provided and may be used in place of latex. Other chemicals in the lab may also trigger allergies. Learn to recognize the signs of contact allergic reaction (skin sensitivity, hives, wheezing) and act to identify and avoid future contact.

3. Laboratory Hazards Overview

3.1 Chemical Hazards

EVERY chemical is a poison, even water; it depends on dose. We handle hazardous chemicals in our every day lives, from pumping gasoline to using chlorine bleach. The keys to safe use of these and any chemical are: understanding the hazards of each chemical; knowing and using safety measures to minimize these hazards. SNF has an excellent safety record.

However, it is easy to become complacent and treat hazardous materials casually. The importance of precautionary measures cannot be emphasized enough. Simple precautions can be a lifesaver; use them as you would a seat belt in a car.

Gas Hazards: Compressed gases pose both chemical and physical hazards. Some of the gases used at SNF are inert; others are toxic, corrosive, flammable, or explosive. The primary health risks posed by gases are the physical hazards (fire, explosion) and inhalation (toxics and corrosives.) General information about some gases used at SNF can be found in section 8 (for more detailed hazard information, please refer to the pertinent MSDS.) Because of these potential hazards, safe use of these gases is strictly determined by state and local regulations, and university policy. Although potential hazards are minimized by use of engineering controls and the toxic gas monitoring system (see section 7 on toxic gas safety), as a labmember, you must still be always aware of the types gases and the hazards posed in the equipment you operate.

Liquid Chemical Hazards: Liquid chemicals present the greatest potential risk for injury: 1. they have to be handled (transported, poured, and mixed) to be used; 2. there's a wide variety, each with a different set of hazards and precautionary measures required for use. Chemicals in the lab can cause severe burns, tissue, and organ damage, and can ignite and explode. The greatest health risks posed by liquid chemicals are physical (fire, explosion), direct contact with skin and eyes (tissue damage), and inhalation (pulmonary damage or long term chronic effects). General information about some of these chemicals and their uses can be found in sections 5 and 6. For detailed hazard information, consult the pertinent MSDS. Make every effort to understand the chemical processes you use and respect the chemicals you work with. Knowing the general rules for how to safely transport, pour, use, and dispose of these chemicals is every labmember's responsibility.

3.2 Electrical Hazards

Electrical shock hazards are present wherever electricity is used. Although equipment is interlocked to prevent operator exposure, you must be aware the electrical hazards for the tool you are using. Burns occur wherever the body completes a circuit connecting the power source with ground. Although the resistance of dry, unbroken skin to electric current is relatively high, the amount of current needed to kill a person is small. It is easy to exceed lethal levels of current, especially if the skin is broken, wet, or damp with sweat.

Unless it is in your training, never open electrical enclosures or cabinets on equipment, even when the power is off. If you feel an electrical "tingle" when you touch a piece of equipment, stop using the tool and immediately notify an SNF maintenance staff person. Never stick your hands, fingers or conductive tools inside equipment. Immediately notify SNF staff of any potential electrical hazard that you notice.

With the exception of most personal electronics devices, any electrical equipment brought into the lab must have prior approval by an SNF staff member. The job of the staff member is to ensure that you will be able to use the equipment in a manner that is safe and consistent with Stanford laboratory policies. Personal electronics devices that do ***not*** require staff approval include: laptops, cell phones, and PDA's. Electronic devices ***not*** allowed to be used in the lab are personal listening devices (iPods and such) as these may prevent the user from hearing alarms or lab announcements.

3.3 Other Hazards

Many tools in the lab use or generate high voltages, ultraviolet, or electromagnetic radiation. Safety interlocks are built into each tool, which prevent direct contact with high voltage sources or exposure to radiation sources during normal operation. However, no system is absolutely foolproof. It is absolutely essential that you, as a labmember, learn and are always aware of the potential hazards, and follow the procedures for safe operation of each tool you are qualified to use.

Ultraviolet Radiation UV exposure is a potential risk in plasma etch, plasma deposition, and sputter tools, where highly energized species are generated. High power UV lamps are used in the aligner and stepper tools in photolithography; as they are mercury-based, they pose a chemical risk. If a UV lamp should break or explode, do not attempt to clean up; instead, isolate the immediate area and call staff.

Electromagnetic Radiation Electromagnetic radiation may be generated by equipment using RF (primarily plasma etch and plasma deposition tools.) If you have a pacemaker, be aware that RF sources are present in the lab. All equipment is shielded to prevent exposure; report any damage to shielding on the equipment or cables.

Cryogenic Hazards Cryogenic hazards are presented by liquid nitrogen ("LN2"). Liquid nitrogen is 77 degrees K (196 degrees C below freezing) and can thus cause freezing burns. Do not handle liquid nitrogen unless your equipment training covers it. Always wear protective gear (thermally insulated gloves and goggles) when handling liquid nitrogen.

4. Where to Find Chemical Safety Information

4.1 Chemical Labels

Each chemical container is required to have a label, provided by the manufacturer, which in addition to composition, contains the following precautionary information:

1. A signal word, which is one of the following: "Caution", "Warning" or "Danger", indicating potential for hazard (in order of increasing potential hazard.)
2. One or more Statements of Hazard, which describe in more detail the hazard presented.
3. Precautionary Measures.
4. First Aid or other information (this may not always be present on the label.)

Remember, only chemicals in their original containers will have these labels. Chemicals that have been dispensed for use or into other containers may not have this information. Since gases are supplied remotely, their label information will not be handy. As a qualified user, it is your responsibility to know the chemicals being used at your station, and the hazards posed by each.

4.2 /MSDS/SDS

Chemicals manufacturers and distributors are required by federal law to provide safety information for each product. The Materials Safety Data Sheet (MSDS) or Safety Data Sheet (SDS) contains information on general composition, physical and chemical properties, toxicology, and storage and handling recommendations of each product. MSDS or SDS documents for all the chemicals that SNF routinely stocks can be found in the hall just outside the Stockroom and online on the SNF wiki. Labmembers wanting to bring in any new chemical or chemical mixture for use in the lab must provide an MSDS or SDS as part of the new materials approval process.

It is highly recommended that you read the MSDS/SDS information for all the chemicals that you use in the lab. That said, MSDS/SDS information can be difficult to read and is written without specific regard to process applications. So, the SNF staff also makes every effort to provide application-specific, chemical hazard information in operating procedures and on the SNF website. You will be expected to know the main hazards, handling requirements, and disposal methods for any chemical you use in the lab.

4.3 Stanford EH&S and SNF Websites

The Stanford University Environmental Health and Safety (EH&S) department maintains an extensive website library on chemical safety. Included in the library is educational material on safety basics, such as how to decipher the terminology in an MSDS form. The Stanford EH&S website is located at: http://www.stanford.edu/dept/EHS.

The SNF wiki contains a lot of information about chemicals and their specific use in the lab. The Materials and Safety sections of the website include: links to MSDS and SDS sheets; lists of acceptable materials in the lab; and procedures for safely bringing in new chemicals and new processes. The website contains links to Operating Procedures for each tool (in the Equipment section) which includes safety information for the chemicals and other hazards at each station. The Processes section of the website includes much information about the standard use of many of the common chemicals found in the lab.

If you do not find the information you require on the website, please consult with any member of the SNF staff. If you have information you would like to share with others, please forward it to any staff member for posting on the SNF website.

5. Liquid Chemicals

5.1 SNF Liquid Chemical Hazard Classes

At SNF, liquid chemicals are categorized into six general chemical hazard classes: corrosive, oxidizer, air/water reactive, flammable, toxic/poison, and non-toxic. Many chemicals fall into more than one class. It is essential that you recognize the chemical hazard class of all the chemicals you are using and understand the appropriate measures required for safe use. The following are the usual safety measures for handling any liquid chemical:

1. Know the main hazards and proper disposal method of the chemical you are using.
2. Use protective gear (safety goggles and face shield, tested and resistant gloves, chemical apron) to prevent direct contact with the chemical.
3. Work only in an appropriately exhausted hood area to prevent inhalation.
4. Know the location of the nearest safety shower and eyewash station.

Corrosive: A corrosive (or "caustic") chemical destroys or permanently damages living tissue. On contact, corrosives can destroy skin and underlying tissues. Splashes in the eyes can cause blindness. Inhalation of vapors can destroy lung tissue. Corrosives in the lab include acids and bases. In case of localized external exposure, promptly flush the affected area with plenty of water, for at least 15 minutes. For more general external exposure, use a safety shower (see section 9.7). Remove clothing while under the shower and flush for at least 15 minutes. Exposure of corrosives to the eyes is extremely serious; flush immediately, either with a spray gun at your wet bench or the nearest eyewash station. Eyes should be rolled up and down, and side to side, continuously, to allow clean water to flush behind the eyeball. For any exposure to corrosives, you should get help. The victim should be taken to the emergency center for evaluation and treatment.

Oxidizer: An oxidizer is a chemical compound that has a pair of electrons to donate to an electron-accepting, reducing agent. Often, they contain reactive oxygen. When mixed with compounds that can act as reducing agents, the result is often a violent reaction, possibly an explosion. Oxidizers should not be stored or mixed with solvents, which generally make excellent reducing agents. At SNF, oxidizers are stored in the chemicals pass-through. One oxidizer is hydrogen peroxide (H2O2). Nitric acid (HNO3) is an oxidizer as well as a corrosive. In the lab, the main principle behind segregation of chemicals is keep oxidizers away from flammable chemicals (namely, solvents) and any combustible materials (some chemicals, materials like lab wipes).

Water reactive: Water reactive describes compounds which very quickly generate heat and/or gas upon mixing with water. These are often concentrated acids or bases. The primary hazard presented by water-reactive compounds is incomplete mixing, which can lead to superheating and explosion. Thus, water-reactive mixtures should never be poured directly into a sink drain. Aspirating water reactive mixtures at the wet benches is standard practice; the high dilution factor and rapid mixing dissipates heat and prevents superheating. Concentrated sulfuric acid and piranha clean are water reactive chemicals.

Flammable: Flammables include most solvents, such as acetone, isopropanol, and methanol. The “flash point” of a flammable is the concentration in air above which the vapors from a flammable can ignite and explode. The source of ignition may be heat (such as a hot plate) or a spark (such as from an electrical tool). Because the vapors can travel over considerable distances, the source of ignition can be far away from the flammables container itself.

To minimize hazards, always work well within the exhausted area of the appropriate bench (behind the red line). The air pulled into the exhaust area will keep the concentration of vapors below the flash point. Where possible, minimize the quantities of flammables used. Before working with flammables, always note the location of the nearest safety shower and fire extinguisher. Flammables should be stored in the designated flammables cabinet; no flammables may be stored in the lab. Flammables must be kept away from oxidizers.

Toxic/Poison: A toxic material is one that has poisonous or harmful effects. There are formal, quantifiable definitions as to what comprises a toxic material and to what degree it is toxic. These definitions are based on lethal dosages for lab animals when administered orally or through inhalation.

Non-toxic: A non-toxic material is one that is not likely to result in harmful effects with normal use. This designation is used sparingly. Pure water is considered non-toxic.

5.2 Liquid Chemical Storage

To prevent accidental mixing of incompatible materials, every chemical in the lab must be stored in the designated area appropriate for its hazard class. Each storage area is designed for safe storage of chemicals of a particular set of hazard classes (i.e., they are appropriately ventilated, chemically resistant, and built against the main physical hazards presented by the chemicals to be stored there.) Thus, it is a safety imperative that all chemicals in the lab be stored appropriately in one of these designated storage areas. No chemicals may be kept in personal storage bins. No chemicals may be stored at any wet benches.

The designated chemical storage areas in the lab are:

Location	General Hazard Class	Chemical Type	Processing Use
Chemicals Pass-through	Corrosives, oxidizers	Acids, bases, oxidizers, separated by compartments	Etchants, cleaning agents
Flammables cabinet	Flammables	Solvents, bases, organics	Resists, developers, solvents
Refrigerator	Flammables	Solvents, organics	Temperature sensitive materials

General use chemical storage The SNF staff keeps general use chemicals stocked in the areas listed in the table above. Please consider your safety and that of others when using these chemicals:

- Follow appropriate procedures for handling and transporting chemicals in the lab (see Appendix). You must be trained and qualified in use of wet benches before working with chemicals.
- When you return chemicals, the outside of the bottles must be clean and dry.
- Containers that are already opened should be used first.
- Notify SNF staff when chemicals are running low (particularly important before a weekend!)

Personal chemical storage Labmembers may keep personal containers of chemicals with the following restrictions.

- The chemical must be approved for use in the lab (if not already approved, see section 5.5).
- It must be acceptable for the process for which you plan to use it (if not, see section 5.5).
- In must be stored in the designated personal storage area for the appropriate hazard class (adjacent to general use storage). No chemicals may be stored in personal bins or at wet benches.
- Personal containers, even if they have the original manufacturer's label, must have the official yellow hazardous materials label and barcode. These are available from SNF process staff members, who will confirm with you the proper handling and storage procedures for your chemical. The information required on the label includes:

- ⇒ Your contact info.
- ⇒ The main hazard group (corrosive, flammable, oxidizer, reactive, toxic/poison, non-toxic).
- ⇒ Chemical Storage Group identifier (see the Stanford Chemical Safety Database and the SNF website) is denoted by a single letter.
- ⇒ Exact name(s) of the chemical.
- ⇒ Date chemical was received.

- You are responsible for removing or disposing of the chemical when it is no longer needed.
- Refer to Appendix E ("Bringing Chemicals into the Lab") for appropriate procedures for transporting chemicals into the lab.

We at SNF understand that, as a research lab, labmembers will always need to test, characterize, and use new chemicals. However, as we are a shared resource, so the actions of any individual can significantly affect the work of others. Thus, it is absolutely essential that every labmember be conscientious about handling of personal chemicals.

5.3 Working with Liquid Chemicals at the Wet Benches

Chemicals may be used only at wet benches. The exception is squeeze or spray bottles containing mild solvents for cleaning (see below). Wet benches are designed for the safe use of chemicals; only designated chemicals or classes of chemicals may be used at each wet station. Every wet bench contains an exhausted area, marked by a red line. All handling of chemicals must take place behind this red line. There are two general types of wet benches in the lab: those used for "Standard" processing and those used for "Non-standard" processing. To use a wet bench, you must be trained and qualified in its safe use.

"Standard" wet benches: These include wbnonmetal, wbnitride, wbclean-1 and -2, wbdecon, wbclean-3, wbmetal, and wbgen2. They may be used only for standard processes and chemicals, as described in the operating procedures for each station. Although very limited, non-standard processing may be accommodated at these benches, any non-standard chemical or procedure requires advance authorization from SNF staff.

Standard wet benches are designed to handle whole cassettes of wafers and have a range of semi-automated modules (hot pots, wet tanks, dump rinsers) for processing cassettes. Any chemicals used at *Standard wet benches* must be used in the appropriate, designated modules. Each *Standard wet bench* has dedicated labware, in order to avoid cross-contamination (do not use labware from one bench at another bench.)

Because designated process modules are used at *Standard wet benches*, no beakers or other chemical containers may be used for processing at Standard wet benches (no Hazardous In-Use forms should be used at any *Standard wet bench*). No chemical containers may be stored at *standard wet benches*. By standardizing chemical usage at these Standard benches, we can ensure predictable, and therefore safe, processing at these stations.

"Non-standard" wet benches

Wet benches: wbflexcorr- 1 and -2, wbflexcorr-3 and -4, wbsolvent, lithosolv, wbmiscres, wbebeam are manual stations and can be used for a broader range of chemicals, within the limits of what is considered chemically compatible for each station. Beakers and other chemical containers may be used at these stations, but only if accompanied by the appropriate blue Hazardous In-Use form. Blank forms are available at each *Non-standard wet bench* and in the gowning room area. The information required on the Hazardous In-Use forms is, as follows:

- Date
- Your contact info (name, phone, Badger login)
- Name of the chemical (no acronyms or abbreviations, please)
- Hazard Category

Use of the Hazardous In-Use forms is strictly enforced; failure to abide by this is considered a gross violation of Stanford safety policy and will be dealt with accordingly. Please remember, this is a shared facility and communication of lab activities that pose potential safety concerns is absolutely critical.

All chemicals at *Non-standard wet benches* must be in-use; absolutely no storage of chemicals is allowed at wet benches.

Squeeze or spray bottles

Bottles containing mild solvents (acetone, isopropanol, or methanol) are the only chemicals that may be used outside of wet benches. They still should, however, be stored at the solvent benches, and they must be properly labeled. They should be used only very sparingly outside of solvent wet benches, because of their low vapor pressure, and they should never be used at non-solvent wet benches nor near any electrical equipment.

Personal Protective Equipment

Personal protective equipment (PPE) is required whenever handling or transporting chemicals in the lab. PPE required depends on the chemicals being used. The table below lists the type of protective gear that is generally used for various chemical types. This table should serve only as a guideline; the operating procedures for each wet bench should serve as the final word.

Chemical type	**Recommended protective gear**
Corrosives or oxidizers	face shield, apron, tested chemically-resistant gloves
Solvents	tested chemically-resistant gloves
Photoresists or developers	vinyl gloves over regular clean gloves

Remember, **you are responsible for your own safety**, **and that of others around you**. SNF provides you with information, recommendations, and necessary resources for you to be able to do your work safely. It is up to you to ensure that you take appropriate precautions for your safety and your fellow labmembers.

Transporting Chemicals in the Lab

Chemicals should be transported using the appropriate transfer carts (white polypropylene for corrosives/oxidizers; metal for solvents/resists/developers.) Chemicals must never be carried by hand. For specific procedures on transporting chemicals in the lab, see the Appendix.

Mixing and/or Heating Chemicals

Chemicals can behave very differently when heated or mixed with other chemicals and present completely different risks. You are performing a non-standard process if you are heating a chemical which is not normally heated, or mixing chemicals that are not normally mixed -- even if the chemicals are normally stocked in the lab. The following hazard classes must never be mixed together:

Corrosives + Flammables = Explosion/fire
Corrosives + Poisons = Poison gas
Flammables + Oxidizers - Explosion/fire
Acids + Bases = Corrosive fumes/heat

Chemically Resistant Labware

When using any wet bench, the labware (cassettes, cassette holders, etc.) must be chemically compatible with the chemicals you are using. The *standard* wet benches (wbnonmetal, wbnitride, wbclean-1 and-2, wbdecon, wbclean-3, wbmetal, wbgen2) have dedicated labware -- no other labware may be used at these benches and the labware at these benches may not be used anywhere else. The *nonstandard* benches (wbflexcorr-1 and -2, wbflexcorr-3 and-4, wbsolvent, lithosolv, wbmiscres, wbebeam) may not have dedicated labware. It is your responsibility to ensure the labware you use will not react with, melt, or dissolve with the chemicals you are using at these benches.

5.4 Chemical Waste Disposal

Disposing of chemical waste in a safe manner is everyone's responsibility. Improper disposal of waste could result in explosion and injury. Violations of proper waste disposal laws may even result in shutdown of our lab. Take time to consider waste disposal in your experimental plans. And remember that waste disposal costs in California are high and everyone bears the economic and environmental burden; minimize the waste you generate.

There are four ways of disposing of liquid chemical waste, depending on the kind of chemical waste generated:

1. Acid Waste Neutralization (AWN) system;
2. HF drain;
3. Solvent collection tank;
4. Local collection.

These are the five general kinds of liquid chemical waste, with different methods of disposal:

1. Standard inorganic acids and bases (AWN)
2. Fluorine-containing acid mixtures (HF Drain)
3. Solutions containing heavy metals (i.e. metal etchants) or other hazardous materials (local collection)
4. Standard solvents (solvent collection tank)
5. Halogenated solvents (local collection; where possible, separate from nonhalogenated solvents)

Detailed procedures on how to dispose of chemical waste are found in the operating procedures for the specific chemical processing wet benches. A general description of the chemical waste disposal systems and methods follows.

The Acid Waste Neutralization (AWN) System - Standard inorganic acids and bases are collected in the AWN drain system, in which effluent is automatically diluted 10-fold and pH-neutralized before being safely drained into the city water waste treatment system. Mixtures containing metals, fluorine, and solvents must NEVER be dumped into the AWN system. (If, by accident, such chemicals are poured into a processing module which normally drains into the AWN, do not drain. Instead, notify a staff member immediately, who will be able to arrange another method of disposal.)

Dedicated station acid hot pots or tanks are plumbed to drain into the AWN system. All dump rinse modules, spin/rinse dryer modules, and plenum flush systems drain into the AWN system. Manual aspirators and sinks at the non-standard processing wet benches (wbflexcorr-1 and -2, wbflexcorr-3 and-4) also drain into the AWN system.

When the AWN system is not functioning, the AWN alarms located throughout the lab will flash. When the alarm is actuated, do not operate any of the wet stations.

HF Drain - High concentrations of fluorine ions are an extreme health hazard (see section 6.4). Therefore, fluoride-ion-containing solutions must be disposed of separately from other waste, using the HF drain system. These solutions include hydrofluoric acid, buffered oxide etchants (BOE's), ammonium fluoride, and any mixtures thereof. Waste from the HF drain is collected in a holding tank located outside the lab, and is regularly removed for treatment by a local service provider.

Dedicated HF and BOE tanks at the standard wet benches automatically drain into the HF waste system. At the non-standard processing wet benches (wbflexcorr-1 and -2, wbflexcorr-3 and -4), HF waste must be manually poured into the specially marked HF drain. These mixtures must NOT be aspirated nor poured down any other drains. If this is done accidentally, notify a maintenance staff member immediately, who may be able to divert the effluent.

Solvent Waste Collection Tanks - Standard, non-halogenated solvent waste is collected into carboys at the solvent wet benches (wbsolvent and lithosolv). The standard solvents are: methanol, isopropanol, and acetone. Standard solvent waste includes these chemicals and photoresist waste. Do not put halogenated waste into the Solvent waste collection tank (see below).

Local Collection - Many chemicals used at SNF cannot be disposed of using the AWN, the HF drain, or the general solvent waste collection tanks. Halogenated organic solvents pose special health and environmental risks for disposal, and so, much be collected located and separated from other kinds of waste. Halogens are the elements in column VII A of the

periodic chart (chlorine, fluorine, bromine, iodine, and astatine). The inorganic acids, such as hydrochloric acid, hydrogen fluoride or hydrofluoric acid, are not included in this category. Halogenated organics are discouraged from use in the lab and some are banned. Examples include chlorobenzene, TCA, borothene, and carbon tetrachloride.

Halogenated organic waste must be treated by incineration at higher temperatures than for other wastes, to prevent the possible formation of highly toxic compounds such as PCB's and dioxin. So separate and properly label halogenated waste from other solvent waste.

Any waste containing toxics and heavy metals *must NOT be disposed of in the city waste treatment center and so must be collected locally. The most common source of metal ions in the lab is in used metal etchants (including gold and chrome etchants). These solutions must absolutely not be aspirated or poured down any drain; they must be collected in waste containers and sent out for hazardous waste disposal. Prohibited heavy metals and other toxics include, but are not limited to, the following:*

Antimony, Arsenic, Barium, Beryllium, Boron, Cobalt, Gold, Manganese, Molybdenum, Selenium, Thallium, Vanadium, Cyanide, Formaldehyde, Phenols, any chemicals on the Federal List of Acutely Hazardous Chemicals or the California List of Extremely Hazardous Chemicals

When in doubt about whether a chemical should be collected locally, check with the SNF staff. See the Appendix for detailed procedures on local collection of chemical waste.

5.5 Bringing New Chemicals or New Processes: Prom Committee

SNF is required to maintain an up-to-date list of the names and amounts of all hazardous chemicals and materials in the lab. Violations jeopardize our ability to operate. In addition, with every new chemical/material brought into the lab, we need to ensure there is:

- a safe way and place to store it
- a safe way to use it
- a safe method of disposing of it and its byproducts
- a way to prevent cross-contamination of equipment groups

All process chemicals and materials used in the lab must be approved by the Prom committee before use. New chemicals and materials are approved for a given process, on a case-by-case basis; use of chemicals/materials for another process will require new Prom committee approval. To register a new chemical, material, or process, please be prepared with the following information:

- Your name and full contact info
- Your PI (Advisor) or Company
- The name of the new Chemical (give all names commonly used):
- If there are secondary new chemicals that must be used with this material (such as a developer for a new resist) list each of them here and supply MSDS's for each of them.
- Complete manufacturer/vendor info, including contact info
- A description of your plans for this new chemical/material/process (application notes and journal articles are very useful.) You should have also checked to see if your chemical or something similar is already approved for use in the lab.

Personal-use chemicals must be appropriately labeled (with identification of owner, contents, and other safety info, as per section 6.2). This is an ever-changing research environment with a lot of chemicals and materials -- we need your help to keep track of them all.

Because SNF is a community of researchers, we all need to be extremely considerate of potential problems posed by the hazards of new materials and how will affect the research of others and, thus, the value of the lab as a research resource. The SNF website should answer most questions and concerns about which chemicals and materials and where their use is acceptable in the lab. Please take time to carefully consider the process flow of your experiment and how it might affect other

labmembers and other downstream processes. If you have any concerns, contact the Prom Committee (snf-promcommittee@lists.stanford.edu), who will help with your questions.

6. Specific Hazardous Liquid Chemicals

6.1 Solvents

Flammable Solvents

Acetone, isopropanol, and methanol may be found in the solvent wet benches. Acetone is often used to dissolve photoresist and other polymers. Isopropanol and methanol are often used for cleaning.

These chemicals are all flammable solvents with low flash points. This means that at sufficiently high vapor concentrations, they can be easily ignited at room temperature and, therefore, pose significant fire hazard. Thus, solvents should not be used on or near hot plates or near any electrical system. Solvents may also ignite or explode when brought into contact with chemical oxidizers (such as many acids) and so should not be mixed with, nor collected in the same waste container as these compounds. Standard solvent waste should be disposed of in the solvent carboy or collected locally.

These and other solvents must be stored in the designated flammables cabinet in the service area and may be transported in the lab only if carried in metal carts. Solvents may be used only in designated solvent hoods.

Chlorinated Solvents

Chlorinated solvents (such as chlorobenzene, trichloroethylene [TCE], and methylene chloride) may be present in some special resist processes, although these have been phased-out of general use. Long term, repeated exposure to some chlorinated solvents is correlated to cancer and liver and nerve damage. Because of environmental hazards, chlorinated solvent waste must be collected in a waste container, separate from other kinds of liquid solvent waste.

Glycol Ether Solvents

Methyl- and ethyl- glycol ethers may be present in some photoresists. These have been implicated in reproductive problems in semiconductor workers. SNF does not stock chemicals which contain these, but instead use ethyl lactate and propyl-glycol ethers which are the accepted replacements. However, some specialty chemicals, such as imported high performance resists, may contain methyl- or ethyl- glycol ethers.

Glycol ethers may be referred to generically as "Cellosolve", but the following names also refer to glycol ether compounds: Methyl Cellosolve, 2-methoxyethanol, Ethyl Cellosolve, 2-ethoxyethanol (2EE), Ethylene glycol mono ethyl ether. Acetate salts of glycol ether compounds may also appear in some specialty photoresist formulations as: Cellosolve Acetate, Ethyl cellosolve acetate (ECA), Ethylene glycol mono ethyl ether acetate, 2-Ethyoxy ethyl acetate**.**

Environmental monitoring studies done of the SNF indicate that there is no risk of significant exposure of these compounds, as long as handling of photoresists takes place only in designated exhausted work areas. As a labmember, your responsibility is to always observe proper chemical handling practices, and to make sure that the people working around you do so, as well.

6.2 Oxidizers

Peroxides

All peroxides are highly oxidizing materials; energy is released when they are reacted. Some peroxides are unstable, and can explode. 30% hydrogen peroxide in water is stocked the lab. Extreme care should be used in mixing solutions containing peroxides. Peroxides are incompatible with all forms of organic solvents and flammable materials.

Sulfuric acid and "Piranha" clean

The heated mixture of concentrated sulfuric acid and 30% hydrogen peroxide is commonly referred to in the semiconductor industry as "piranha clean." This mixture is an extremely aggressive oxidizer, used primarily for removing photoresist and, in sequence with other chemical mixtures, to remove contaminants (i.e., the "RCA" or pre-diffusion clean process). The proportions of sulfuric acid and hydrogen peroxide used will depend on the particular wet bench and application.

The piranha solution self-heats when mixed and immediately destroys organic materials it contacts (photoresist, cleanroom wipes, vinyl or latex gloves, skin.) Piranha vapor is extremely caustic, so the piranha mix should be used only under an exhaust hood. Boiling piranha spatters, so always wear protective gear when working over a hot pot. Piranha is incompatible with all solvents and flammable materials. It reacts violently when mixed with base. Do not add water directly to piranha to try to cool it; sulfuric acid is water reactive, so adding water will cause heating (not cooling!) and can lead to an explosion.

Nitric Acid

Nitric acid is also water reactive (heating upon addition of water). Nitric and acetic acids are components of pre-mixed Aluminum etchants. All oxidizers should be kept away from solvents, bases, and flammable materials.

6.3 Hydrofluoric Acid and Fluoride Containing Chemicals

Hydrofluoric acid (HF) and related fluoride-containing mixtures (such as ammonium fluoride or BOE) pose particularly dangerous health hazards. Concentrated HF produces extremely painful, deep tissue burns. Lower concentrations of HF are particularly insidious, as the initial contact may produce no pain at all, although tissue damage may continue over days following exposure. There are a lot of horror stories about HF. Take them seriously. For procedures on emergency treatment for HF exposure, see section 9.10.

HF is a small molecule and a weak acid, so it can travel very quickly through skin and into tissues. Systemic damage can occur when fluoride becomes distributed throughout the body. Negative fluorine ions bind very readily to positive calcium and magnesium ions to form insoluble salts. This can result in severe electrolyte imbalance, including hypocalcemia (loss of calcium) and hyperkalemia (too much potassium). Since calcium and potassium regulate the heart, irregular beating and cardiac arrest are manifestations. "Deaths have been reported from concentrated acid burns to as little as 2.5% BSA [body surface area exposed to skin contact]." (From eMedicine website.)

BOE's ("buffered oxide etchants") and Pad Etchants are pre-mixed solutions of HF and buffer, or ammonium fluoride (NH4F). Although ammonium fluoride is a neutral salt of HF, it readily dissociates to yield fluorine ions, and so presents nearly the same hazard as HF. All BOE's contain nearly the same total fluorine as concentrated 49% HF.

Calcium gluconate is used treat exposure to HF. This compound provides extra calcium ions which can scavenge free fluorine ions before they penetrate and damage tissue. In cases of skin contact, calcium gluconate gel must be applied immediately to the area of contact. In cases where systemic damage is a risk, calcium gluconate is administered by a healthcare professional, intravenously. Tubes of calcium gluconate gel, along with instructions for use in case of contact exposure, are mounted to the front panel of every wet bench where HF and fluorine-containing chemical mixtures are used. More about emergency treatment of HF exposure can be found in section 9.10.

Pure hydrogen fluoride is an extremely toxic gas which very easily dissolves in water. "Hydrofluoric acid" describes this solution form. HF easily passes between gas and liquid phases; so HF- (and NH4F-) containing solutions will emit toxic fumes. Although SNF lab safety precautions tend to emphasize protection against skin contact with fluoride-containing solutions, remember to avoid inhalation of the fumes by always working under fully exhausted areas of the wet benches.

For more detailed info about HF, check the links on the SNF Safety website.

6.4 Alkali/Bases

Alkaline compounds, or bases, are the chemical opposite of acids, and may react violently when mixed with them. They are most commonly used in the lab in lithography and etch. Alkalis are caustic, so protective gear should always be worn when working with them to prevent contact with skin and eyes.

KOH and TMAH Etchants
Heated solutions of 25%-30% potassium hydroxide (KOH) or tetramethyl ammonium hydroxide (TMAH) are commonly used to chemically etch silicon. These etchants may be used only at the wbflexcorr stations. TMAH presents special hazards (see next section.)

TMAH
Tetramethyl ammonium is a nerve agent (specifically, a ganglion blocker.) Its hydroxide form can allow rapid penetration through corrosive damage to the skin. Deaths have resulted in an industrial accident where 25% TMAH spilled onto workers even though they rinsed within a minute of exposure. TMAH is used at lower concentrations (2-3%) in most photoresist developer solutions. Health effects have been documented for large area exposure at these concentrations, so PPE should always be worn when handling developer solutions directly.

Removers and strippers (PRS 3000, PG Remover and related chemicals)
These are organic base mixtures, which are used for removing photoresist from wafers containing metal films (which are corroded by conventional piranha clean.) Unlike other acids and bases used in the lab, these strippers are not water-based and are combustible; by some criteria, they may be considered solvents. These strippers must never be directly mixed with strong oxidizers.

6.5 Gallium Arsenide

Gallium arsenide (GaAs) and its by-products are extremely toxic. All persons working with GaAs should develop especially good "housekeeping" habits and be constantly aware of how arsenic might be generated during processing. Avoid direct physical contact with GaAs and anything that comes into direct contact with GaAs. When breaking and scribing GaAs wafers, work under the designated wbflexcorr-1 and -2 exhausted hood and wipe down all surfaces afterwards to prevent spreading of GaAs dust. Follow handling and decontamination procedures at each equipment where GaAs processing is done.

- ***Solid GaAs Waste***

Any GaAs waste, no matter how small, must be considered hazardous, including GaAs-contaminated labwipes and old proximity-cap silicon wafers. Place GaAs waste in an airtight zip-lock plastic bag and place in the "Solid GaAs Waste" can located under the wbflexcorr-1 and -2. Stanford University Health and Safety will pick up full cans on request.

7. Hazardous Gases

7.1 Storage

Most all hazardous process gases are located in reinforced storage vaults away from the lab. Gases are stored by chemical class in individual gas cabinets and are monitored by an automated toxic gas detection system. Remote gases are delivered to the lab through a series of valves, regulators and flow control systems. Utility gases, such as nitrogen, argon, and oxygen, are kept in liquid form in large storage tanks outside the lab. Few gas bottles are stored in the lab; any that are, must be in-use and must be secured (chained or bracket-mounted) to prevent getting knocked over.

7.2 Handling and Usage

There are extreme hazards presented in working with gas cylinders, so only trained and qualified staff may install, disconnect, or change out gas cylinders. Here are some of the risks involved with some of the gases at SNF.

- Gases, such as phosphine and arsine, are extremely toxic. Small leaks may be fatal.
- Cylinder gases may be at pressures as high as 3000 psi. When punctured or cracked open, these cylinders may become rockets.
- Gas regulators are designed to handle specific gases. If not properly chosen and installed, leaks or explosion may result.
- Improper installation and purging can result in contamination of the gas cylinder.

7.3 Toxic Gas Detection System

SNF has an automated toxic gas monitoring system consisting of remote sensors located throughout the lab and the gas pads and vaults. Depending on the sensor, when triggered, the system launches a preconfigured sequence which may include the following actions: 1. activation of gas shut-off valves; 2. activation of audible alarms; 3. notification of the appropriate response teams. This automated function ensure the appropriate response will be always taken in the event of a toxic gas emergency and, thus, enables the lab to run 24 hours/day, 7 days/week. More information about the toxic gas alarm can be found in section 10.2.

8. Specific Hazardous Gases

8.1 Pyrophoric (flammable) Gases

These gases will spontaneously ignite in air within a critical concentration range.

Silane (SiH4)

It is used for deposition of polysilicon, amorphous silicon, nitride, oxide, and oxynitride films. It is a high-pressure gas. When exposed to trace amounts of air or moisture, silica dust can form.

Dichlorosilane (SiH2Cl2)

It is used for deposition of polysilicon and amorphous silicon. It is low vapor pressure liquid source. Like silane, it will form dust when exposed to trace amounts of air and moisture.

8.2 Corrosive Gases

Hydrochloric acid (HCl)

HCI gas is extremely corrosive to almost everything, including stainless steel. It is used for clean/etching deposition chambers.

Ammonia (NH3)

NH3 gas is a severely corrosive alkaline vapor with a pungent odor. It is shipped in the cylinder as a liquid under its own vapor pressure of approximately 9 atm. NH3 gas is used in oxynitride and nitride film deposition (plasma and CVD.)

8.3 Highly Toxic Gases

These gases described here are severe pulmonary irritants and acute systemic poisons. Overexposure can cause either sudden or delayed death due to lung destruction. Although each has a characteristic smell, the odor threshold is not much lower than

the toxic exposure level. The gases described here are mixed at low concentrations in carrier gases (silane, hydrogen, or nitrogen) and used as film dopants in LPCVD and Epi2 systems.

Phosphine (PH3)
PH3 is a colorless, highly toxic gas with an odor described as fishy.

Diborane (B2H6)
Diborane is a colorless, poisonous, pyrophoric gas with an odor described as a repulsively sweet.

Arsine (AsH3)
Arsine is a colorless, poisonous, flammable gas with an odor described as garlicky.

8.4 Non-toxic Gases

These gases are considered non-toxic because they do not generally pose an immediate risk to health and safety. However, they can be asphyxiants and may pose other health risks at high concentrations or with long-term exposure.

Nitrogen (N2) and Clean Dry Air (CDA)
House nitrogen and Clean Dry Air are plumbed throughout the lab for general use in equipment and other utilities. The supply can run up to 80 psi, which can pose a hazard: do not direct an N2 or air gun toward your own body (especially the face and eyes) or toward anyone else.

Etch Gases
SF6, CF4, O2, N2, CHF3, C2ClF5, CBrF3, and C4F8 are commonly used in plasma etchers. Although the gases themselves generally pose low health risk, their by-products in etch systems are less benign. Make sure to follow proper operating procedures for pumping down or purging etch chamber systems following processing.

8.5 Cryogens

Nitrogen, argon, helium, hydrogen, and oxygen are stored in liquid form outside the lab and are evaporated to be delivered to the lab in gas form. LN2 should not be used in an enclosed space because of the risk of asphyxiation. LN2 can also burn tissue on contact, so protective gear must be worn whenever handling.

9. How to Respond in Emergencies

9.1 Allen/Annex Building Emergency Response Procedures

Emergency response procedures and emergency contact information for the Allen/Annex Building are posted throughout the lab and the building (look for the brightly colored signs near exit doors, fire alarms, fire extinguishers, and building phones.)

WHAT TO DO IN AN EMERGENCY

TYPE OF EMERGENCY	RESPONSE
Health Threatening Fire, toxic spills, gas leak, leave building and go to EAP#104, located on Serra Mall, just past the water fountain on the sidewalk	• Pull the fire alarm, if alarm is not already sounding. • Leave the building immediately. • Meet at the Evacuation Assembly Point **(EAP #104)** • DO NOT re-enter the building until cleared.
Major Earthquake	• Take cover; wait for shaking to stop. • Leave building & meet at **Evacuation Assembly Point (EAP # 104)** • DO NOT pull the fire alarm unless there is a health-threatening hazard.
Life-Threatening Medical Emergency (if in doubt, treat as an emergency)	• Call out for help. • **Dial 9-911 or 911 immediately** (DO NOT hang up until told to do so.) • DO NOT move victim unless necessary. • **First aid kit/AED/Oxygen Units near room 158 and in Annex, near room 130.**
Non-Health Threatening Emergency (Building and facilities)	• Emergencies during work hours call **Kenny Green (650) 804-2032**. • After hours, call **Work Control at 3-2281**.
Electrical Power Outage	• Emergency backup lights should come on within 15 seconds. Office area operations will resume when power is restored; SNF lab operations require staff support to reset.
Chemical Spill < 30ml	• Only if your training covers it, use proper protective equipment and clean up; otherwise, contact help as for large spill.
Spill > 30 ml or will take longer than 15 minutes to clean up	• During work hours, notify staff on lab page phone or **SNF Duty Phone (650) 521-7306** • After work hours, call **EH&S at (650) 725-9999**
Odor in the Lab	• Leave the immediate area. • If no alarm is sounding, make sure others leave (use Lab page phone) • During work hours, notify staff on lab page phone or **SNF Duty Phone (650) 521-7306**

9.2 Building and Lab Evacuations

Although the SNF has an excellent safety record, the reality is that hazardous chemicals and other physical hazards are ever-present in the lab. In the case of an emergency, the priority is to ensure that everyone is safely away from these hazards. Depending on the extent and seriousness of the situation, an evacuation may be invoked just for the lab or for the entire building.

Building Evacuation:

When an emergency arises which requires the evacuation of the building, the fire alarm system will sound throughout the entire building. The fire alarm is automatically activated by smoke and fire detectors located throughout the facility and the building. Some toxic gas detectors in the lab and support areas may also activate the general fire alarm. The fire alarm can be activated manually as well, by pulling the handle at any one of the pull stations located throughout the building.

When the fire alarm is activated, the alarm strobe will flash and a very loud klaxon will sound. When a fire alarm sounds, leave immediately. Do not take time to finish your tasks in the lab. Do not take time to remove your bunnysuit or pick up your belongings. Leave the lab and the building through the nearest exit and go to the Evacuation Assembly Point (EAP). Provide assistance to others as necessary. Provide information that may be of assistance to Emergency Response personnel at the EAP. Only after the Fire or Police Departments declare the scene safe will you be allowed to re-enter the building.

Anyone in the building may call for an evacuation. This is an appropriate response to "an unforeseen event that calls for immediate action to protect individuals, the environment, or property" [Stanford University Administrative Guide Memo 25.2]. Examples of such situations include: fire, smoke, strong chemical vapors, or large chemical spill. To call an evacuation, pull the fire alarm. This will immediately notify the Palo Alto Fire Department and the appropriate Stanford University Emergency Response teams.

All labmembers should familiarize themselves with the location of lab and building exits, the Evacuation Assembly Point, fire alarm pull stations, and fire extinguishers.

Response Procedures:

1. Evacuate immediately to the Evacuation Assembly Point (EAP).
2. Do not re-enter the building until cleared to do so.

Laboratory Evacuation:

Some situations may warrant an evacuation of just the laboratory area, rather than the whole building. A lab evacuation may be invoked automatically or manually.

An automatic lab evacuation is activated by toxic gas alarms located in certain isolated, ventilated areas of the lab or support facilities. In the case of a localized toxic gas alarm, the blue warning lights and will flash and the alarm will sound only inside the lab. When in the lab, you must leave immediately. Do not take time to finish your tasks in the lab. Do not take time to remove your bunnysuit or pick up your belongings. Leave the lab through the nearest exit and assemble in the office area outside the lab.

Response Procedures:

1. Evacuate the lab immediately to the office area outside the lab.
2. Do not re-enter the lab until cleared to do so.

A laboratory evacuation should be manually invoked in hazardous situations which are isolated to the lab and do not pose a health or safety risk to building occupants outside the lab. Such situations include:

- Chemical spill
- Unusual odor
- Any other situation in which the health or safety of lab occupants may be of immediate concern.

A laboratory evacuation may be called by an announcement over the PA system (red phones.) Anyone may call an evacuation. ***Unless specifically otherwise instructed by a staff member***, you should respond as would for a building evacuation: Leave immediately through the nearest lab exit: do not take time to finish your tasks in the lab, remove your bunnysuit, or pick up your belongings. Meet in the office area outside the lab, for further instructions.

Response Procedures:

1. Announce evacuation over the PA system (red phones).
2. Evacuate immediately to the office area outside the lab.
3. Do not re-enter the lab until cleared to do so.

9.3 Major Earthquake

In a major earthquake, the greatest hazard you face while in the lab is falling objects. Toxic gases are not likely an immediate hazard, as the automatic shut-off valves will be activated under this condition. In the event of an earthquake, take cover in a doorway or under a solid table. After the earthquake, leave the lab and go to the designated assembly point.

Response Procedures:

1. Take cover.
2. After shaking stops, check nearby co-workers, and evacuate to the Assembly Point.
3. Do not pull the fire alarm unless there is a health-threatening emergency.

9.4 Life-threatening Medical Emergency

If a fellow labmate is experiencing a medical difficulty and cannot be easily escorted to the nearby medical service providers, you should call for emergency medical services. Dial 911 to contact the Palo Alto Fire Department (X9-911 from any campus phone). Follow any instructions the dispatcher gives and stay on the line until told otherwise.

Do not move the victim unless necessary. Moving an injured person can result in further, more serious injury. Do not touch the victim, if you suspect electric shock.

Response Procedures:

1. Dial 911 immediately. Do not hang up until told to do so.
2. Do not move victim unless necessary.

9.5 Non-health Threatening Emergency

A non Health-Threatening Emergency is "an emergency in which there is not a clear potential for serious injury to any person. (If unsure whether an emergency is health-threatening or non health-threatening, assume it is health-threatening.)" [Stanford University Administrative Guide Memo 25.2]. This might include building and facilities problems such as large water leak.

Response Procedures:

1. Call SNF maintenance staff.
2. If unavailable, call Building Facilities.
3. After hours, call Work Control (X3-2281) and notify Primary SNF Contacts.

9.6 Electrical Power Outage

Response Procedures:

1. Remain calm. Emergency backup lights should come on within 15 seconds.
2. When emergency lights come on, leave the building from the nearest exit.
3. Notify SNF Primary Contacts

9.7 Chemical Spills

Chemical spills that occur outside the ventilated area of a chemical wet bench can pose inhalation and contact hazards for other labmembers. This is particularly unsafe if the chemical is a volatile, corrosive, or reactive, material, if it is generating vapor or heat, or if the spill has occurred in or around electrical equipment. The response procedures to be taken will be determined by whether the spilled chemical which through evaporation or chemical reaction, is generating vapor or heat and thus poses a hazard to people in other parts of the lab. (Remember, you should always be familiar with the potential hazards of the chemicals that you work with!) Unless you are trained and specifically instructed by a staff member who has evaluated the situation, DO NOT make any attempt to clean up the spill yourself.

For non-vapor-generating, non-reactive chemical spills, the hazard is confined to the immediate area. The priority is clear the immediate area and ensure that others do not enter the area.

Response Procedures:

1. Clear the area.
2. Block off the area using yellow "Hazard" tape (available in the chemical spill cart).
3. During normal weekday, working hours, call SNF staff.
4. After hours and on weekends, call EH&S at X5-9999 and notify SNF Primary Contacts
5. Provide as much information you can about the incident to the persons responding.

For chemical spills which generate vapors or heat, there is a risk to the others in the lab at large; therefore, a laboratory evacuation must be performed.

Response Procedures:

1. Clear the area.
2. Pick up the red PA phone and make the following announcement at least three times: "There is a chemical spill. Evacuate the lab immediately."
3. During normal weekday, working hours, call SNF staff.
4. After hours and on weekends, call EH&S at X5-9999 and notify SNF Primary Contacts.
5. Provide as much information you can about the incident to the persons responding.

9.8 Odors in the Lab

With proper use of wet bench and disposal procedures, the laboratory should be free of odors. In general, if you smell something, there is either an equipment malfunction or someone has neglected to follow appropriate chemical handling procedures. However, on some occasions, the odor may originate from outside the lab (such as food in the office area or construction outside.) If you smell something in the lab, notify a staff member right away. Provide as much information as you can about the location and possibly identity of the smell.

Response Procedures:

1. Notify staff member.
2. Clear the affected area.
3. Wait for instructions from staff, who will investigate.

9.9 Chemical Exposure to Corrosives (other than HF)

Always, in case of exposure to corrosive chemicals, promptly flush the affected area with plenty of water. For non-HF containing solutions, flush for at least 15 minutes (for HF-containing solutions, see section 9.10).

If the area of contact is small and on an extremity (i.e., hand), then a DI spray gun, DI tap, or even a dump rinse module at a wet bench, may serve if these are the closest sources of water. If the area of contact is large or on the body, you must immediately go to the nearest safety shower. Do not remove clothing; activate the shower and then remove all clothing under the shower. Continue flushing the affected areas with water for at least 15 minutes, while someone gets help.

An exposure of corrosive to the eyes is very serious; because the eyeballs sit rather loosely in their sockets, a splashed chemical can work its way around the eye to damage the optic nerve. If chemical is splashed into an eye, immediately begin flushing both eyes with wafer for at least 15 minutes. Both eyes should be held open with the thumb and forefinger. Victim should roll eyes up and down, and side to side, continuously, to allow clean water to wash away any corrosive that may have gotten behind the eyeball. While the victim is at the eyewash, someone else should be calling the doctor for further instructions.

For any exposure to corrosives, the victim should be taken to the emergency center for evaluation and treatment. If the corrosive contains HF, ammonium fluoride, or other fluorine ion containing solution, follow the procedures in section 9.10.

Response Procedures:

1. Rinse affected area for at least 15 minutes. Remove clothing covering the affected area while flushing with water.
2. Call for help.
3. If mobile, the victim should be escorted to a local emergency medical provider (see section 9.13) for evaluation and treatment. If not, call 9-911 for emergency medical help.
4. Following treatment, the injury must be reported to an SNF manager (see section 9.12)

9.10 Chemical Exposure to HF or Fluoride-ion Containing Solutions

Any exposure to HF or other fluoride-ion containing solution must be treated immediately, as fluorine ions will quickly penetrate skin to damage tissue underneath. Chemicals stocked at SNF which contain fluorine ions include: 49% HF, 6:1 BOE, 20:1 BOE, 50:1 BOE, concentrated ammonium fluoride, and PAD etch. Concentrated HF will immediately cause extremely painful burns on contact. However, more dilute HF solutions will not cause any pain; yet can still cause deep tissue or systemic damage. If contact with HF (or related solution) is suspected, treat the incident as an HF exposure. Calcium gluconate gel is used as an antidote for HF exposure to skin. Tubes of calcium gluconate are located at every wet bench in the lab, along with instructions on its use. Calcium gluconate is for external use only and must not be used for chemical exposure to eyes.

Response Procedures:

1. IMMEDIATELY rinse the affected skin area with lots of water. Being careful to wash the acid away from other parts of your body, especially finger/toe nails where acid can get trapped.
2. Remove all clothing exposed to the HF.
3. Continue rinsing for 1-2 minutes. Do not rinse for more than 5 minutes. Do not dry the skin.
4. Call for help.
5. Obtain Calcium Gluconate gel (available at all wet benches in the lab).
6. Puncture the tube using the inverted tube cap. Apply gel over the entire affected area.
7. Using gloves, gently massage the gel into the skin. Take the gel with you and continue to apply fresh gel while en route to the Emergency Room.
8. Elevate burned extremities, if possible.
9. Go immediately to a local emergency medical provider (see section 9.13.)
10. Tell them you have Hydrofluoric Acid on you.
11. Continue to apply fresh gel (and gently massage it in) while waiting to be treated.
12. Following treatment, the injury must be reported to an SNF manager (see section 9.12)

9.11 Fire

Lab fires may result from the ignition of flammable chemicals and the combustion of materials. Ignition of chemical solutions on hot plates is a major cause of lab fires. When you are done, always be sure to turn off hot pot heaters and hot plates. Always disable wet benches when you have finished working; the Badger interlock will automatically disconnect power.

In the event of a small fire, you may use a fire extinguisher to put out the fire. Immediately report the fire to an SNF staff member (or notify SNF Primary Contacts after hours.)

Response Procedures:

1. In the event of a large fire, pull the fire alarm or call 9-911. Evacuate the lab.
2. If your clothes ignite, DO NOT PANIC. To extinguish the fire:
    i. get under a safety shower; or
    ii. stop, drop (to the floor), and roll

9.12 Reporting Accidents

All injuries must be reported to the Department of Risk Management. Accident forms are available online (http://www.stanford.edu/dept/Risk-Management/) and in labeled red folders, kept in the Shipping and Receiving area. How to submit these forms can be found at http://adminguide.stanford.edu/25_6.pdf . In summary:

Accident/Incident/Exposure Form (SU-17)

This form must be submitted in the event of injury of any personnel, Stanford or non-Stanford. This form must be submitted to Risk Management within 24 hours of injury and signed by the injured party and an SNF staff manager.

Employee's Claim for Workers' Compensation Benefits (DWC Form-1)

This form must be submitted in the case of injury of Stanford personnel. This form must be signed by a University representative/supervisor/administrator and then given or mailed to the employee within 24 hours of the accident, incident or exposure.

Employer's Report of Industrial Injury (Cal-OSHA Form 5020)

This form must be submitted within 24 hours of occurrence when an industrial injury or occupational disease suffered by a Stanford employee results in:

- lost time beyond the day of injury, or
- medical treatment by a physician in a clinic, hospital, emergency room, or medical office.

A Workers' Compensation Lost Time Report (Form SU-16)

Form SU-16 must be submitted when a Stanford employee has lost one full day or more following the day of an accident or the first day of a work related illness. Form SU-16 is submitted online when the employee returns to work.

9.13 Medical Providers for Work-Related Injuries

Unless you have completed a Pre-Designated Physician form found at http://www.stanford.edu/dept/Risk-Management/docs/forms/predesig.html, Stanford University's medical providers for work related injuries are listed below.

For Non-Life Threatening Work-Related Injuries

During work hours, Stanford employees, including staff, researchers, post-docs, and grad students, should go to the Stanford Occupational Health and Safety Center, located on campus.

Location:
Environmental Safety Facility (ESF)
480 Oak Road, Room B15
Stanford, CA 94305-8007
Phone: (650) 725-5308
Fax: (650) 725-9218
http://www.stanford.edu/dept/EHS/prod/researchlab/IH/SUOHC/

Hours:
Monday – Friday
8:00 am - 5:00 pm

For Life-Threatening Emergency Care
For immediate life threatening injuries go to the nearest Emergency facility (eg. Stanford Hospital Emergency room, phone (650) 723-5111).

10. Alarms

10.1 Fire Alarms

Appearance and location of the alarm strobes: Fire alarm strobes are located in the lab and throughout (both inside and outside) the Allen/Annex building. The strobe is a small, rectangular, white light, mounted in a bright red frame.

Alarm conditions: In an alarm situation, the strobe flashes and a very loud, pulsing klaxon sounds. In an alarm condition, all the alarms in the lab, Allen, and Annex buildings should go off. The toxic gases in the lab will shut off immediately and the Palo Alto Fire Department will be called.

Action to be taken under alarm conditions: Immediately evacuate the lab and the Allen/Annex buildings to the designated evacuation point.

10.2 Toxic Gas Alarms

Appearance and location of the alarm beacons: The toxic gas alarm beacons are located in the lab and throughout (both inside and outside) the Allen/Annex building. The beacon is a large, cylindrical, blue lamp.

Alarm conditions and action to be taken: In an alarm condition, the beacon flashes and a very loud klaxon sounds continuously. There are two levels of alarms.

In a Level 1 alarm condition, the toxic gas problem is isolated to a gas enclosure. In this case, only the alarm inside the lab will be activated. The lab must be evacuated immediately, but the building need not be. Toxic gases in the lab will be shut off automatically.

In a Level 2 alarm condition, the toxic gas problem might not be isolated in an enclosed area. In this case, the fire alarms (white strobes) as well as the toxic gas alarms (blue beacons) throughout the buildings will be activated. The lab as well as Allen/Annex must be evacuated to the designated assembly point. Toxic gases in the lab will be shut off and the Palo Alto Fire Department will automatically respond.

10.3 Acid Waste Neutralization Alarm

Appearance and location of the alarm strobes: The Acid Waste Neutralization (AWN) system alarms are located throughout the lab, generally, over wet benches in each section of the lab. For specific alarm locations, check the lab safety map. The alarm consists of a yellow light that flashes when active.

Alarm conditions: The alarm for the Acid Waste Neutralization (AWN) system will flash when the system is no longer able to sufficiently neutralize the acid and base waste. The alarm is not audible. Always check the alarm before beginning processing on an acid/base wet bench.

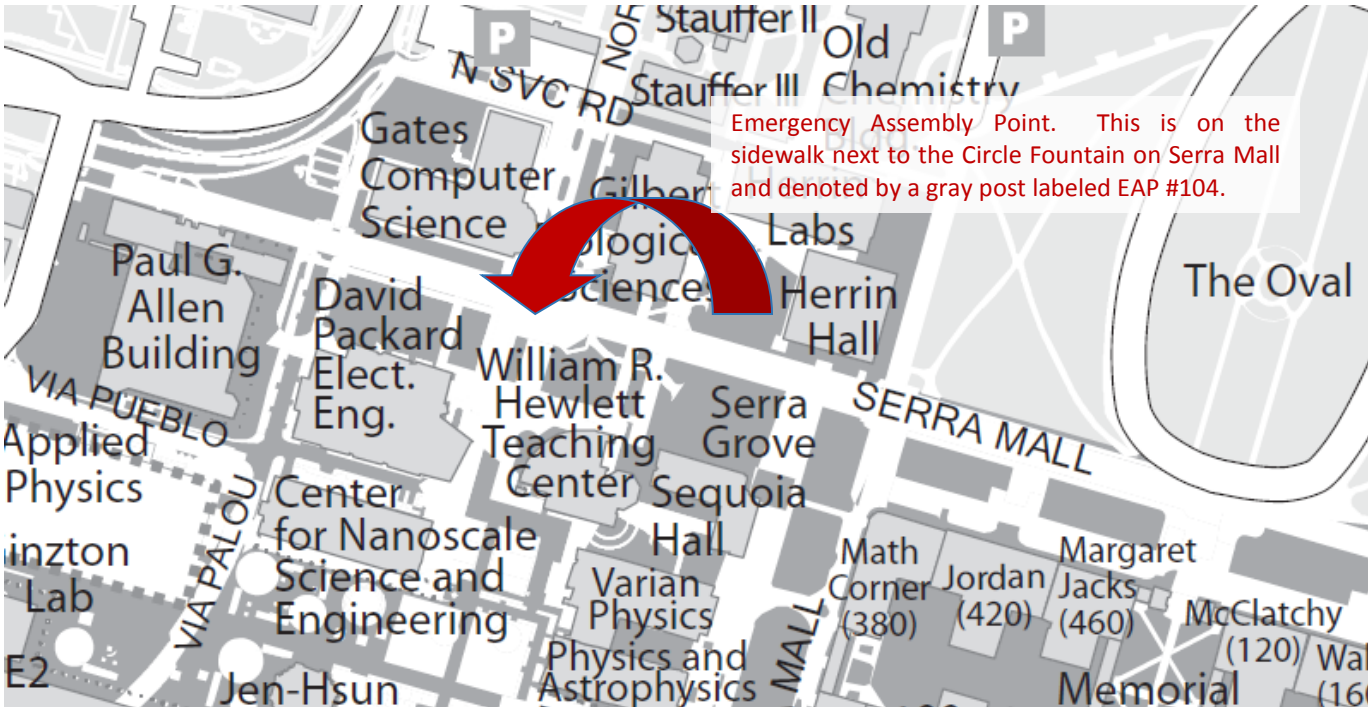
Action to be taken under alarm conditions: When this occurs, labmembers are prohibited from using any of the acid/base wet benches until the alarm situation is cleared. Under alarm conditions, no solutions of any kind may be aspirated, drained, or poured down the drain of any acid/base wet bench. Solvent benches are not affected.

11. Lab and Building Maps

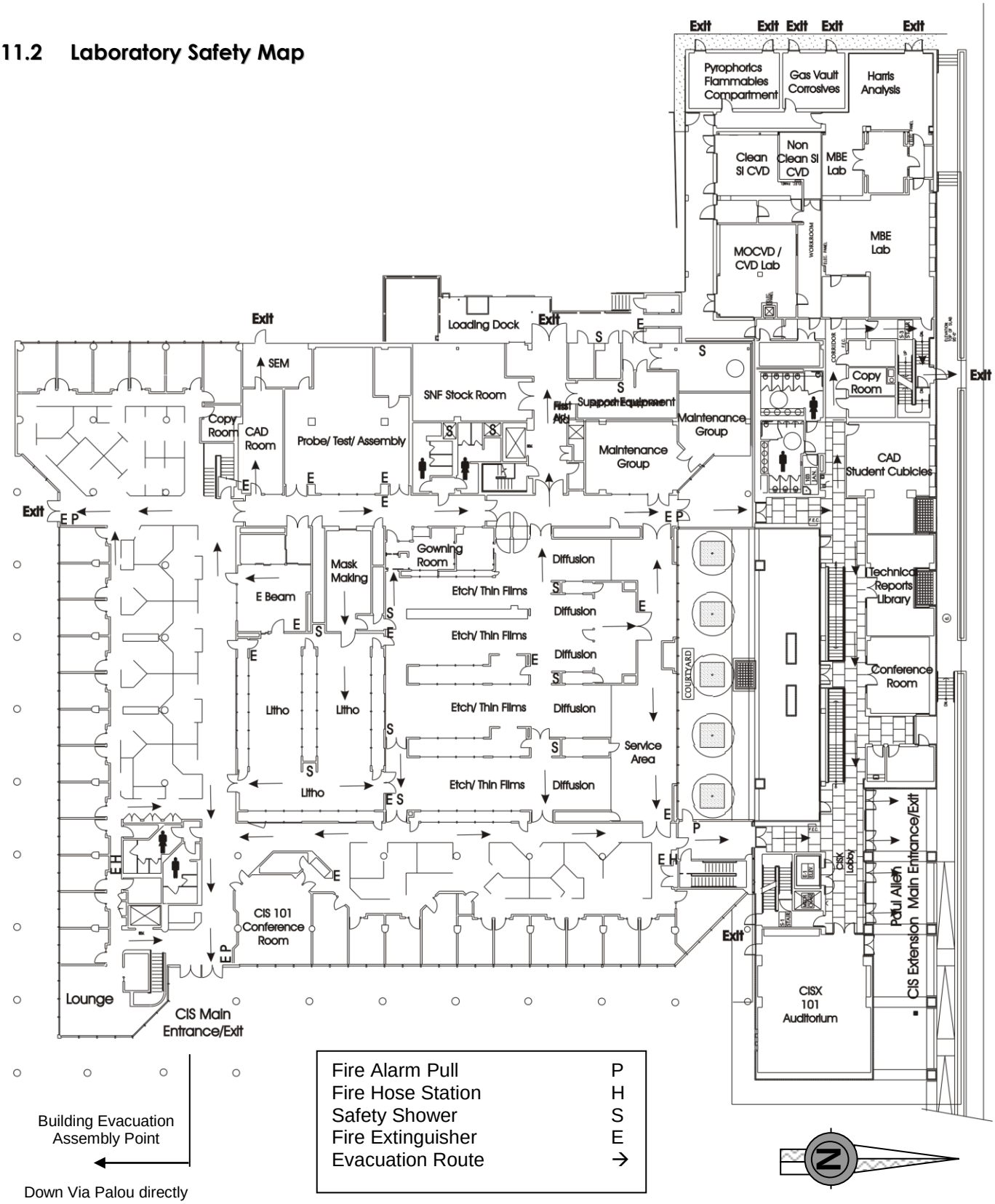
11.1 Lab and Building Evacuation Assembly Point

For any fire alarm and Level 2 toxic gas alarm, all building inhabitants must immediately evacuate the lab and the Allen/Annex buildings and go straight to the designated assembly point.

When evacuating, leave immediately; do not stop to remove your bunnysuit or pickup your belongings. Leave the lab through the nearest marked "EXIT" door (remember: not all doors in the lab lead to the outside, so only use the marked ones!) Do not stop to save your work -- your life is more important than a few wafers! And remember, any delay jeopardizes not only your personal safety, but also the safety of the emergency response team members. On leaving the lab, continue out the building to the designated assembly point. Wait there for further instructions from a member of the emergency response team.



11.2 Laboratory Safety Map



Fire Alarm Pull	P
Fire Hose Station	H
Safety Shower	S
Fire Extinguisher	E
Evacuation Route	→

Building Evacuation Assembly Point

Down Via Palou directly In front of the Ginzton Lab (see diagram on page 29)

12. Appendices

Appendix A: Transporting Corrosives in the Lab (Acids and Bases)

Transfer Carts: Chemicals must be transported using transfer carts (in the lab) or chemical bottle carriers (from the stockroom into the service area only). The transfer carts for acids and bases are made of white polypropylene and kept next to the Chemicals pass-through when not in use.

Protective Gear: Should be worn whenever handling hazardous chemicals.

- Chemically-resistant apron
- Face shield (over safety goggles)
- Chemically-resistant gloves

Procedures:

1. Open the pass-through door slowly. Do not open, if the hallway side is open.

2. Bring the transfer cart next to the pass-through. Remove the chemical you need from the pass-through and place it into the transfer cart.
   - Use opened containers first.
   - Check the container label to ensure you have the correct chemical.

4. Close the pass-through door.

5. Transfer your chemical to the wet bench. Pour your chemical according to standard procedures. Rinse and dry the outside of the bottle, if any chemical has been dripped. Return the bottle to the transfer cart.

6. Return the transfer cart to the pass-through.

7. Open the pass-through door slowly (make sure the hallway side is not open).

8. Return the chemical bottle to the pass-through. Make sure:
   - Bottle lid is on tight.
   - Outside of the bottle is clean and dry.
   - Chemical is returned to its proper location.

9. Close the pass-through door.

10. Empty chemical containers should be placed in the red-taped areas on the top shelf of the pass-through.

Appendix B: Transporting Flammables/Litho Chemicals in the Lab
(Solvents, Resists & Developers)

Transfer Carts: Chemicals must be transported using transfer carts (in the lab) or chemical bottle carriers (in the service area only). The transfer carts for solvents, resists and developers are made of metal and kept next to the Flammables storage cabinets when not in use.

Protective Gear: Provided for handling hazardous chemicals.

- Chemically-resistant apron
- Face shield (over safety goggles)
- Chemically-resistant gloves

Procedures:

1. Open the Flammables cabinet or refrigerator door slowly (to prevent vapors from being pulled out.)

2. Bring the transfer cart next to the storage area. Remove the chemical you need from the storage area and place it into the transfer cart.
   - Use opened containers first.
   - Check the container label to ensure you have the correct chemical.

4. Close the storage cabinet or refrigerator door.

5. Transfer your chemical to the workstation. Pour your chemical according to standard procedures. Clean and dry the outside of the bottle, if any chemical has been dripped. Return the bottle to the transfer cart.

6. Return the transfer cart to the Flammables storage area.

7. Open the Flammables cabinet door slowly.

8. Return the chemical bottle to the storage area. Make sure:
   - Bottle lid is on tight.
   - Outside of the bottle is clean and dry.
   - Chemical is returned to its proper location.

9. Close the Flammables cabinet or refrigerator door.

10. Empty chemical containers should be placed in the designated plastic bins on top of the Flammables cabinets.

Appendix C: Local Collection of Liquid Hazardous Waste

Waste that must be collected locally:

Any waste that cannot be aspirated to the AWN, drained into the HF waste system, or into the solvent waste tanks, must be collected locally. Such waste includes chlorinated solvents and liquids containing metals or toxics. For a more detailed description, see section 5.4 of the Laboratory Safety Manual or the SNF website. If you have any doubts about how to dispose of a chemical, consult with an SNF staff member.

Where liquid waste collect is done:

Local collection of chemical waste may be done only at the Non-standard wet benches (see section 5.3 of the Laboratory Safety Manual). You must be trained in the use of a Non-standard wet bench before you may use one.

How to do liquid waste collection:

- ***Obtain a clean, empty waste container.*** (Do not use empty chemical containers, which have not been decontaminated.) Clean, empty containers are stored next to the Flammables cabinet, in the service area behind the furnaces. These containers might be previously used for handling chemicals; however, they have been chemically decontaminated. The chemical labels on these containers should be defaced; if not, use the large black marker located there to cross out the label. The clean containers that are supplied are made of polypropylene, which is inert to most, but not all, chemicals used in the lab.

    - If the chemical waste you plan to generate is not compatible to polypropylene (concentrated nitric acid, for example), you should plan on bringing in a chemical container that is. (Some glass containers may be available in the Stockroom.)

    - If you are working with multiple chemical mixtures, make sure to use separate containers for collecting different types of waste (acid versus base, for example.) Mixing waste may lead to unwanted side-reactions, including heat and explosion.

- ***Obtain a blank hazardous waste disposal labels.*** Blank labels and clean bottle tops, are available next to the clean containers. Fill out the pertinent information on the hazardous waste disposal label. Attach the label to the waste container (they can be tied to a handle.)

- ***Pour the used chemical into the labeled waste container.*** This should be done at the wet bench, using a chemically compatible funnel for safe pouring. Rinse the container you used for processing with water three times, pouring the rinse water each time into the waste container. Pour the water used to rinse the substrates into the waste container.

- ***Cap the container***, making sure that the outside of the container is clean and dry. Make sure the hazardous waste label is securely attached.

- ***Transport the container using the transfer cart.*** Place the container on the appropriate hazardous waste shelf in the chemicals pass-through.

Appendix D: Solid Hazardous Waste Disposal

What is solid hazardous waste?

Chemically contaminated objects are considered solid hazardous waste. These include gloves, lab wipes, swabs, plastic syringes and syringe filters. These must not be disposed of in the regular garbage cans because they can off-gas vapors and they may harm our custodial staff. Chemically contaminated solid waste should be categorized by chemical class:

- flammable (solvents, photoresist, etc.)
- corrosive and other waste (acids and bases, other chemicals)

"Sharps" are objects that can cut or puncture skin. These include silicon or silicon germanium wafers (not GaAs, which must be disposed of as chemically hazardous waste), broken glass beakers, razor blades/exacto knives/scalpels, or hypodermic needles. Out of concern for safety of our custodial staff, sharps must not be thrown into the regular garbage cans.

How to dispose of solid solvent/resist/flammable waste

- Work under an exhausted area, to avoid inhaling chemical fumes.
- Place the waste into a plastic bag (ZipLoc bags are available throughout the lab).
- Secure the bag, so that it is air-tight.
- Place the waste in one of the designated Solid Flammable waste containers.
- If you are working with chlorinated solvent waste, follow the procedures for "corrosive and other waste" below. Do not place chlorinated solvent waste into the Solid Flammables waste container.

How to dispose of corrosive and other chemically contaminated solid waste

- Work under an exhausted area, to avoid inhaling chemical fumes.
- Place the waste into a yellow hazardous waste bag, available in the safety cart.
- Secure the end of the bag.
- Double-bag, by placing the waste into a second hazardous waste bag.
- Fill out and attach a hazardous waste tag (available in the safety cart.)
- Place the waste in the chemicals pass-through area for pickup.

Sharps

Sharps should be disposed of in the sharps collection box. This is a large, blue and white cardboard box located between the Flammables storage cabinets. When the box is full, notify an SNF staff member. The box will be taped shut; the entire box will be disposed of at once, and replaced with a new box.

Sharps should not contain hazardous chemicals; i.e., beakers should not contain liquid photoresist or corrosives. If you have a sharp object contaminated with chemicals, place the object into a box (an empty wafer box will do), tape it shut, and double-bag in labeled hazardous waste bags, according to the procedures above.

Appendix E: Bringing Chemicals into the Lab

1. **Chemicals used in the lab must be Prom committee approved.** Approval requires a list of tools which will be exposed to chemicals either directly or indirectly (i.e., present on substrates), the process used (heating, mixing, recipe, etc.), and provisions for storage and waste disposal.

2. **Chemical containers must be labeled and barcoded.** Include chemical name/composition, your contact info, and date. Obtain a yellow label and barcode from a staff member. The tradename for a chemical mixture can be used as long as the MSDS is on file with **Prom committee**.

3. **No chemical powders or crystals are allowed in the cleanroom.** Powders and crystals can be dissolved and mixed into solutions in the Utility/Wafersaw room before being brought into the cleanroom.

4. **Use secondary containment when transporting chemicals ANYWHERE.**

5. **Chemicals may NOT be brought through the gowning room.**

6. **To bring a chemical into the lab,** you may either:

    a. **Contact a staff person** who will place your chemical in the chemicals passthrough; or,

    b. **Place your chemical in the service area**, using the door at the back of the lab. You may then gown up to retrieve your chemical. To do this, you must:

        - **Use secondary containmen**t (cart)
        - **Label your chemical container** with contents, your contact info, and date. This MUST be visible on the outside of the container (and on the outside of secondary containment, if used.)
        - **Place it in appropriate storage** as soon as possible. Remember: unattended and/or unlabeled chemicals WILL be disposed of.
        - **Note: the service door is locked after hours.**

2. **Remember to discard your chemical** when you are finished with it in the appropriate manner.