LABORATORY & CHEMICAL SAFETY GUIDE

Optical & Semiconductors Devices Group
Department of Electrical & Electronics Engineering
IMPERIAL COLLEGE

LABORATORY & CHEMICAL SAFETY

The purpose of this guide is to promote safety awareness and encourage safe working practices in the laboratory. These brief guidelines should serve as a reminder of things you can do to work more safely and are applicable to all users of the laboratory. For more detailed *assessment or your suggestions, observations or concerns* please refer to the personals below and not strictly in the same order.

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If you are not satisfied with the help or advice from the people listed above please refer to Professor Richard Syms who has the ultimate responsibility for safety as Head of the Group.

Safety Philosophy

We would like to keep laboratories and clean rooms as an informal and friendly place to work and would neither like to make or enforce rules unnecessarily, nor to "baby sit" users. Guidelines on laboratory safety and chemical use are formulated on the basis of past happenings in laboratories, basic chemical knowledge, the properties of individual chemicals, and common sense. Safety guidelines were developed in many cases in response to specific incidents of laboratory and chemical misuse. In addition, Health & Safety Executive has issued guidelines under the Control of Substances Hazard to Health (COSHH) which covers all chemical handling and use in a workplace. These guidelines are mandatory and they apply to all chemical handlers and users.

In spite of guidelines and staff supervision, the primary responsibility for safety rests with the individual. A responsible, considerate worker with an understanding of the working of the laboratory, its equipment, basic chemistry, common sense, and an instinct for self-preservation will have little trouble with laboratory and chemical guidelines or chemical safety.

The staff cannot oversee or supervise operations all the time. Under these conditions, any inconsiderate user can endanger his or her own as well as other's safety. A majority of problems, incidents and violations in the laboratory are the result of haste. Haste, however, makes waste, as the old saying goes. Working under such conditions, you can waste your samples, waste time and money, get crummy results, break things, and endanger yourself and others by being careless.

If you do not have time to do things correctly and safely, with adequate time for thought, please stay away from the laboratory.

Your safety in the laboratory is determined not only by your own actions but also by the actions of those around you. Since the staff is not around most of the time, the users are often in the best position to observe the behaviour of others. You may point out about the violations of the safety guidelines to the offender and to the staff at the first available opportunity. (Please do not start an argument and if you think the reaction by the individual was inappropriate report it to the staff.) The use of laboratories and clean room facilities depend on maintaining a safe working environment. Thoughtless behaviour, violations of the laboratory or chemical guidelines would not be tolerated.

All research workers are expected to adhere to safety guidelines and maintain safety standard expected in a university facility where direct staff observation is not possible.

Laboratory Hazards

Hazards in the laboratory fall into three general categories:

Equipment: A wide variety of equipment is used for different activities. Most of the equipment is delicate, sensitive and expensive. Before you use any equipment you must learn about its operation and its safety implications. Misuse of equipment can lead to injury delay in project work and substantial cost in repair bill.

Gases: A variety of compressed gases are used, some of which may be toxic, corrosive, flammable, or explosive. These hazards have been minimised by the use of proper equipment, proper confinement, ventilation, safety valves, etc., and by procedural controls. You must learn about the safe handling of gases before embarking on their use. An accident with any of these could be catastrophic.

Chemicals: Acids, bases, etching solutions and solvents are commonly used in materials chemistry and device fabrication. These are "hands on" hazards which are hard to control by engineering controls only. These chemicals can cause severe burns, tissue damage, organ damage, asphyxiation, and genetic damage if used improperly. You must take chemical safety instructions before using any chemical.

In addition, improper use of solvents can result in a major fire. These chemicals even they look ordinary, are definitely not hazard free.

Filling in a COSHH form should not be for the fulfilment of legal obligation only, this is an opportunity to learn about hazards associated with chemicals, their safety implications and how to handle and use them safely.

General Safety Awareness

- Familiarise yourself with all aspects of safety before using any equipment.
- Be alert to unsafe conditions of the equipment, procedures and actions, and call attention to them so that corrections can be made as soon as possible.
- Label all storage areas, appropriately, and keep all chemicals in properly labelled containers.
- Date all chemical bottles when received and when opened.
- Note expiry dates on chemicals.
- Note storage conditions and adhere to them.

- Familiarise yourself with the appropriate protective measures when exposed to the following classes of hazardous materials.

Flammable	*Carcinogen*
Corrosive	*Compressed Gases*
Toxic	*Poisons*

- Segregate chemicals by compatibility groups for storage.

- Post warning signs for unusual hazards such as flammable materials no naked flames or other special problems.
- Pour more concentrated solutions into less concentrated solutions to avoid violent reactions (i.e. add acid to water, not water to acid).
- Avoid distracting other worker.
- Use equipment only for its designated purpose.
- Position and secure apparatus used for chemical reactions in order to permit manipulation without moving the apparatus until the entire reaction is complete.

Personal Safety

- Always use extracted wet benches for chemical work.
- Always wear safety glasses or goggles at all times in the laboratory.
- Always wear laboratory coat/apron in the laboratory.
- Appropriate gloves should be worn as needed.
- Appropriate shoes should be worn in the laboratory.
- Wear breathing mask as and when appropriate.
- Only trained personnel may use breathing apparatus.

Personal Hygiene

- Wash hands before leaving the laboratory.
- Never mouth suck anything in a pipette in the laboratory.
- No food or drink is allowed in laboratories or areas where chemicals are used or stored.
- No food should be stored in a laboratory refrigerator.
- Never eat or drink from the laboratory glassware.
- Keep exposed skin covered in the laboratory.

Fire Prevention

- Aware yourself of ignition sources in the laboratory and service areas (open flames, heat, electrical equipment).
- Purchase chemicals in quantities that will be used in not distant future.
- Always store flammable liquids in appropriate cabinets.
- Do not store incompatible reagents together (e.g., acids with organic solvents).
- Do not store ethers or similar chemicals for extended periods of time as explosive peroxides could form.
- Date chemicals when received and opened.
- Make sure that all electrical cords are in good condition and all electrical outlets are earthed. Remain out of the area of a fire or incident if you are not in position to help.
- Familiarise yourself with siting and condition of fire extinguishers. Broken seals mean fire extinguisher has been used and need be recharged.
- Do not use fire extinguishers unless you are trained and feel confident to do so.

Housekeeping

- Eliminate safety hazards by maintaining the laboratory work areas in a good state of order.
- Maintain clear passages to the laboratory exit.
- Always keep bench tops, extracted wet benches, floors and aisles clear of unnecessary material.
- Wipe down bench tops and other laboratory surfaces after each use.
- All equipment should be inspected before use.
- If experiments must be left unattended, place a note next to experimental apparatus indicating the chemicals involved and possible hazards and your name and a number where you can be reached in case of an emergency.

- Keep the laboratory floor dry at all times. Attend to spills immediately and notify other lab workers of potential slipping hazards.
- Only authorised personnel should do maintenance work on laboratory equipment.
- Sink traps should be flushed with water on a regular basis to prevent the release of chemical odours in the laboratory.
- All compressed gas cylinders should be securely chained or clamped to a rack.
- Take empty cylinders to the empty cylinder bay for collection. Unnecessary delays accumulate rent that is usually much more than the price of the gas.

Emergency Procedures

- Please familiarise with the location, use and limitations of the following safety devices.

Eye Wash Station	*First Aid Kit*
Breathing Apparatus	*Fire Alarm*
Spill Cleanup Materials	*Fire Extinguisher*

  - Clean up all small spills immediately. If a spill is large and is expected to poses a hazard to others in the laboratory, stop the activity or equipment if possible, and call for help.
  - If volatile, flammable, or toxic material spill, shut off flames and spark-producing equipment at once and evacuate and call one of the above members of staff for help to deal with the spill.
  - In the event of fire or explosion, call for help.
  - Maintain a clear path to all safety equipment at all times.

Personal Protective Equipment

Protection of health and safety of workers at work is a legal requirement for all according to Health and Safety Executive Directive. Familiarise yourself with the safety guidelines and adhere to them.

Eye Protection

Splashing chemicals or flying objects are possible at any time in a laboratory environment. Eye protection should be worn in the laboratory all the time. Safety glasses, Goggles, and Safety Visors are available in the laboratory. Please select the one most appropriate for your work.

Laboratory Coat

The laboratory coat is designed to protect the clothing and skin from chemicals that may be spilled or splashed. Please wear laboratory coat in the chemistry laboratory all the time

Aprons

An apron provides an alternative to the lab coat. It is usually made of plastic or rubber to protect the wearer against corrosive or irritating chemicals. An apron should be worn over garments that cover the arms and body, such as a laboratory coat.

It is important you keep the protective clothing in good condition. Dirty and damaged clothing should be cleaned and repaired or replaced. Dirty protective clothing is a hazard in itself.

Hand Protection

Always wear protective gloves in the laboratory specially when handling chemicals. Because certain glove types are not impervious in contact with chemicals, please select one on the basis of the material being handled and particular hazards involved.

Before use, check to make sure the gloves are in good condition and free from holes, punctures, and tears.

Glove manufacturer /supplier and the Material Safety Data Sheets (MSDS) accompanying product in use are good sources of specific glove selection information.

Here are few suggestions for the selection of gloves:

PVC	protects against mild corrosives and irritants.
Latex	provides light protection against irritants and limited protection against infectious agents.
Natural Rubber	protects against mild corrosive material and electric shock.
Neoprene rubber	good for working with solvents, oils, or mild corrosive material.
Cotton	absorbs perspiration, keeps objects clean and provide a limited fire retardant properties.
Thermal gloves	should be used when handling small hot objects.

When removing gloves, peel the glove off the hand, starting at the wrist and working toward the fingers, turning inside out. Avoid contacting the working surface area of gloves during removal.

Wash hands as soon as possible after removing protective gloves.

Foot Protection

Foot protection is designed to prevent injury from corrosive chemicals, heavy objects, electrical shock, as well as giving traction on wet floors.

Please wear sturdy shoes that cover the foot completely. These will provide the best protection. Avoid shoes that expose feet in any way.

Breathing Mask and Breathing Apparatus

Certain laboratory procedures can produce noxious fumes and contaminants. This usually happens when engineering controls cannot successfully minimise or eliminate the potentially harmful fumes. Also different people have different sensitivity when exposed to certain chemicals, in these circumstances one may require a respiratory protection. There are two types of protection available, a Breathing mask or Breathing apparatus.

Breathing masks are simpler in use and are available with filters for specific contaminants. In laboratory work these are most likely to be a practical choice. VWR International, Aldrich and RS catalogues provide information for the selection of suitable breathing mask and filters appropriate for certain hazardous contaminants.

Breathing apparatus is slightly more complicated kits and not easy to use in a laboratory environment. These are usually used in an emergency. Only trained personals are allowed to use them.

Laboratory Safety Equipment

Extracted Wet Bench

Extracted wet bench capture, contain, and expel emissions generated by hazardous chemicals or chemical reactions. All laboratory experiments with chemicals should be done in extracted wet bench. While it is possible to predict the release of undesirable or hazardous effluents in most laboratory operations, surprises can always happen. Therefore, the extracted wet bench offers an extra measure of protection.

Fume hood should not be used for long-term chemical storage.

Chemical Storage Cabinets

Storage of flammable and corrosive chemicals in the lab should be limited to small quantities as for as possible. Flammable materials should be stored in flammable material storage cabinets.

Storage outside of the cabinet should be limited to materials used in the current process and must be returned after use to the appropriate storage cabinets. Leaving chemicals on benches or working areas is hazardous and is not acceptable.

Plastic cabinets are designed for corrosion resistance and used for storing acid and other corrosive materials.

Acids and other corrosive chemicals in the chemistry laboratory are stored under the fume hoods.

Refrigerators

To prevent potential safety hazards, the length of storage of chemicals should be kept to a minimum and refrigerators should be periodically inspected.

Eyewash Stations

A bowl-mounted eyewash station, which provides continuous water flow through a plumbed unit, is available in the chemistry laboratory and is accessible to all laboratory personnel. Always flush the eyewash line before use.

Eye wash solutions are also available in all laboratories.

Water or eyewash solutions should not be directly aimed onto the eyeball, but rather, aimed at the base of the nose. This increases the chance of effectively rinsing the eyes free of chemicals (harsh streams of water may drive particles further into the eyes).
If wearing contact lenses remove them as soon as possible to rinse eyes of any harmful chemicals.

Fire Safety Equipment

Please familiarise yourself about the location of Fire Alarms. Fire Extinguishers are located near exits in most laboratories.

Only use a fire extinguisher if the fire is controllable and you know how to use the extinguisher safely. If you can't put out the fire, leave immediately and trigger a fire alarm. If fire alarm is activated inform immediately to

Dr Tom Tate	*(ext 46208)*
Dr Munir Ahmad	*(ext 46260)*
Dr John Stagg	*(ext 46260)*
Mr John Grover (Technical Services Manager)	*(ext 46161)*

General Laboratory Equipment Safety

Glassware

Accidents involving glassware are a leading cause of laboratory injuries. These can be avoided by following a few simple procedures. In general, be certain that you have received proper instructions before you use glass equipment designed for specialised tasks that involve unusual risks or potential injury.

Here are few safety rules:

- Handle and store glassware carefully so as not to damage it or yourself.
- When inserting glass tubing into rubber stoppers, corks or when placing rubber tubing on glass hose connections:
- Protect hands with a heavy glove or towel.
- Lubricate tubing or stopper with water or soap solution and be sure that the ends of the glass tubing are fire-polished.
- Hold hands close together to limit movement of glass should fracture occur.
- Substitute plastic connections for glass whenever possible to decrease the risk of injury.
- Use glassware for vacuum work that is designed for that purpose.

When dealing with broken glass wear hand protection when picking up the pieces.
Use a broom to sweep small pieces into a dustpan and store glass pieces in a designated bin for broken glass.

Heating Devices

Electrical devices that supply heat in laboratories include:

Hotplates
Tube & Box Furnaces
Heating Mantles
Hot-Air Guns
Oil Baths

Improper use of any one of these could result in fire or burns to the user.

Before using any heating device:

- Check to see if the unit has an automatic safety shutoff in case of overheating.
- Note the condition of electrical cords and have them replaced as required.
- Make sure the apparatus has been maintained as required by the manufacturer.
- Check to see that all heating units in use without automatic shut-off have been turned off before leaving an area for any extended period of time.

- Flammable or combustible solvents should not be used in a heated bath or placed near the bath. Oil baths must always be housed in a chemical fume hood.

Vacuum Systems

- Familiarise yourself with the operations of the vacuum system in use. (If you are not familiar with the functions of *Rotary, Diaphragm, Diffusion or Turbo Pumps*, please make an effort to learn about them. Improper use can lead to accidents, serious damage to pump, substantial cost in repair or replacement of the pump and of course delay in project work.)
- Make sure the service cord and switch are free of observable defects and accessible in case of emergency.
- Always use a trap on the suction line to prevent liquids from being drawn into the pump.
- If gases or vapours are being drawn through the pump, a cold trap should be used in the suction line to prevent contamination of the pump oil.
- Place a tray under the pump to catch any oil drips.

First Aid & Emergency Procedures

Please familiarise with the first aid and emergency procedures so that mishaps can be speedily contained. It is the responsibility of the injured person to report any injury or property damage to **Mr John Grover, Departmental Safety Officer.** Required forms and instructions are available with the departmental safety officer's office. It is advisable to call the College Health Centre (South Side) and let them know about your injury before visiting the centre for material help.

First Aid

Wounds

Cleanse area with water as appropriate.
Small cuts and scratches place sterile pad over wound and apply gentle pressure evenly with the opposite hand. If direct gentle pressure does not control bleeding, raise the area above the level of the heart. Apply dressing plaster as appropriate.

If there is significant bleeding place sterile pad over wound and apply gentle pressure and call the Health Centre (South Side) immediately for help and advice.

Thermal Burns

First degree burns are characterised by redness or discoloration of the skin, mild swelling and pain. These can be treated by rinsing or immersing in water for at least 10 minutes and applying a skin cream as appropriate, and seeking further medical treatment as needed.

Second and third degree burns are characterised by red or scared skin with blisters (second degree), white or charred skin (third degree). Immediate first aid is to clean the area if possible and keep it dry and call Health Centre (South Side) for medical help immediately.

Chemical Burns

If hazardous chemicals should come into contact with skin or eyes, follow the first aid procedures below.

Skin: Remove garments as required and rinse the affected area with large quantities of water for at least 15 minutes (sink, shower, or hose).
Do not apply burn ointments/spray to affected areas.
Call the Health Centre (South Side) for medical help without delay.

Eyes: Rinse area of eyes, eyelids, and face thoroughly with lukewarm water for at least 15 minutes at the eye wash station and call the Health Centre (South Side) without delay.

CHEMICAL SAFETY

All chemicals have some degree of risk attached to their use and it is important before any work is started that a careful investigation is made into the nature and the reaction of the chemicals in use in order to determine whether a hazardous situation could develop. The aim is to protect people against the risks to their health whether immediate or delayed. If the assessment indicates a risk then the hazard must be prevented or controlled and the necessary controls must be properly used and adequately maintained.

COSHH Requirement

No work should be carried out which exposes a person or his/her colleagues to any substance hazardous to health unless a suitable and sufficient assessment of the risks created by that work and of the steps needed to meet the COSHH requirements has been made.

To comply with the COSHH requirements all work must be protected by risk assessment. Risk assessment must be completed by the person carrying out the work and signed by the supervisor who will determine the course of action appropriate to the experiment before work proceeds.

COSHH Assessment Requirements

People carrying out assessment should note the hazards associated with chemicals which can be classified under the general headings:

1. *Toxicity*
2. *Flammability*
3. *Explosibility*
4. *Biological effect*
5. *Generally offensive*

The first step to take when working with chemicals is to find out as much as possible about the concerned chemicals and the possible by products from published sources. Manufacturers and suppliers has a legal obligation to inform users about the potential hazards associated with the use of their products. In case of new materials where information is not available the judgement must be exercised in predicting whether a material will be hazardous. This may not be always predictable. All personal precautions such as the wearing of gloves, eye protection, and any antidote required should be made available to be ready for use.

Toxic chemicals **:** It will be advisable to find out if a safer substitute can be used. Personal cleanliness reduces the possibility of ingestion and wearing of personal protective equipment eliminates absorption of the material through skin. Protective clothing and gloves should always be examined carefully before use, for example pinholes in gloves can cause serious injury by allowing chemicals to enter the gloves and attacking the skin. All chemicals must be handled inside the extracted wetbench. Any antidotes required should be prepared and made readily available for instant use. Information about the toxicity of chemicals is documented in safety data sheets.

Flammable Materials**:** These materials should be kept to minimum quantity, source of ignition excluded and correct type of fire extinguisher placed nearby. Materials with a flash point below ambient temperature require very careful consideration. The vapour pressure/temperature curve

should be carefully examined to check whether an explosive concentration of the substance in air can develop. All possible sources of ignition should be removed.

Highly Reactive or Explosive Materials: These require very careful handling and reactions involving them should be kept to the smallest possible size. Exothermic reactions should be classified in this category, particular care being taken to ensure that cooling systems do not fail with the result that reaction get out of control

Generally Offensive Materials: These produce unpleasant working conditions and frequently the chemicals are toxic too. The best way to minimise unpleasant smell is to handle these chemicals in extracted wet bench.

Lachrymators and Smokes: These cause intense eye pain and copious flow of tears. Their effects on the eyes and air passages can be serious but the symptoms and pain may disappear after few minutes in the open air. These materials should always be handled in the extracted wet bench.

Extra care should be taken when handling substances which may react violently when mixed. This should also be borne in mind when storing chemicals.

Methods of Absorption

There are three main routes by which individuals can be exposed to chemicals:

1. ***Through Skin***
2. ***Oral Ingestion***
3. ***By inhalation***

Through Skin: Certain parts of the skin are more active than others, namely sweat and sebaceous glands, hair follicles, etc. and areas against which clothing rubs are particularly vulnerable. Localised irritation is most common form of complaint and is enhanced by chemicals which absorb moisture and dehydrate the skin. Corrosive chemicals cause varying degrees of injury from relatively mild attacks to severe burns. Toxic chemicals may be absorbed into the bloodstream after passage through the skin. Eyes are particularly sensitive area of the body and are irritated by the physical pressure of even the smallest object. When the material is corrosive and toxic pain and injury can be serious.

Oral Ingestion: Oral ingestion of chemicals, apart from the deliberate act, is mainly due to accidental occurrence and can be easily avoided.

Inhalation: Inhalation is the most common method of absorbing materials into body. A very large volume of air inhaled by an average person per day means that even the very small amounts of toxic material become important and very large surface area of the lungs increases the chances of the material being absorbed rapidly. Some even may be absorbed into the mucous lining of the air passage and be brought up in the sputum and swallowed, thereby presenting additional method of absorption.

Symptoms of Exposure

May include Irritation, Burning Sensation, Coughing, Wheezing, Laryngitis, Shortness of Breath, Headache, Nausea and Vomiting.

Acute Effects

Harmful if Swallowed, Inhaled or Absorbed through Skin.

Exposure may be extremely destructive to Eyes, Skin, Respiratory Tract and Mucous Membrane.
Exposure may also cause, Nausea, Headache, Vomiting and Convulsions.
Inhalation may be fatal as a result of Spasm, Inflammation and Edema of the Larynx and Bronchi, chemical Penumontis and Pulmonary Edema.

Chronic Effects

Prolonged exposure can cause:
Lung irritation, Chest pains, Pulmonary Edema.
Damage to Blood, Kidneys, Liver, Lungs and Mucous Membranes or irreversible Tissue damage.
Narcosis of sufficient degree to increase accident proness, impair self rescue, or materially reduce work efficiency.
Effect on Central Nervous System.
Risk of irreversible effects.

Precautions

Almost all hazardous properties of chemicals are largely affected by the size and the and dose and therefore it is necessary, to be aware of the exposure limits commonly called **Threshold Limit Value (TLV).** It is a guide considered as being without hazard in a person's normal working. For a number of chemicals another exposure limit is introduced which is called **Short Term Exposure Limit (STEL)** and is defined as the maximal concentration to which a worker can be exposed for a period up to 15 minutes continuously without suffering from Irritation, Chronic or irreversible tissue change or Narcosis of sufficient degree to increase accident proneness, impair self rescue or materially reduce work efficiency. No more than four periods of this concentration in a day are permitted. **Occupational exposure limits (TLV*)*** for chemicals are recorded in safety data sheets. Consult the relevant safety data sheet for guidance. If there is a potential risk then consideration should be given to how the risk can be eliminated or reduced to meet approved standards.

Steps Necessary For Safe Working

Wear appropriate Protective Clothing, Safety Goggles, Chemical Resistant Gloves.
Use only in a extracted wet bench.
Avoid contact with Skin, Eyes or Clothing.
Do not breath vapour.
Keep containers tightly closed.
Wash thoroughly after handling chemicals.
In case of any mishap seek medical advice as appropriate.

Specific Chemical Hazards

Acetone and Flammable Solvents
Acetone is widely used throughout the facility. It is a very flammable solvent with a low flash point, (i.e. it can be ignited at a low ambient temperature). Because of this it presents a significant fire hazard. A spill of a gallon bottle of acetone could cause a catastrophic fire or explosion.

It should not be transported except in chemical buckets. Solvents should also be handled with care in the hoods and not used near hot plates. Spilled solvent can be ignited by the hot plates. The resulting fire could easily be drawn up into the exhaust ducts, again with catastrophic consequences.

Spilled solvents can react explosively with chemical oxidising agent present, e.g., peroxides, nitric acid. Spilled solvents should be contained immediately with chemical spillage absorbent. Seek help as required. If you require help please contact is
Dr Munir Ahmad (ext 46260).

Hydrofluoric Acid
Hydrofluoric acid, HF, presents a significant hazard for personal injury. It is widely used in the semiconductor processing. It is only allowed in two designated wet benches, one in staff clean room and other in the chemistry lab. It is available in 40% concentration, diluted, and as the active component of buffered HF, Buffered Oxide Etch. It is used for etching silicon dioxide and for stripping the native oxide prior to further processing.

HF is a very hazardous chemical, much more so than any other acids we use. Its danger comes from its colourless, odourless appearance and its systemic poisoning.

At the concentrations used in the laboratory, a HF "burn" is initially painless. You may not even know that you have gotten a splatter on your hands, arms, face, or in your gloves. The acid however will silently eat away at your flesh. The fluoride ion is not consumed in this process and is soluble in tissue, so the damage penetrates deeper and deeper, until it comes to the bone. About this time the excruciating pain begins. It is too late, however, to reverse the considerable tissue damage. At some point, it enters your blood stream and goes everywhere scavenging Ca ions, totally messing up the ionic chemistry of your nervous system. At some point, if left untreated, you die.


HF burn (courtesy of UC Berkeley)

Simple washing of HF splash is not sufficient to prevent damage. It does not wash off; it is already dissolving you and will continue to do so until you receive medical attention specific to HF burns (including deep injections to neutralise the penetrated acid). Be sure that medical personnel know that it is HF burn and know that it requires specific treatment different from a common acid burn.

HF etches silicon dioxide as well as glass. It must not be kept in a glass bottle, used in a glass beaker or disposed in a glass waste bottle. Plastic laboratory ware is available for this purpose.

HF must only be used in the designated extracted wet benches *(chemistry laboratory and staff clean room). It is not acceptable to use HF or HF containing solutions in any other areas.*

Piranha Mixture
Liquid piranha is a common name applied to a mixture of Hydrogen Peroxide and Sulfuric Acid (typically 1:5). It is extremely aggressive toward carbonaceous materials (e.g. flesh and photoresist residue, equally).

It also removes heavy metal contamination. It is also used for cleaning Si wafers.

We have difficulty disposing of this mixture because the waste continues to react and decompose for a long period of time. This builds up pressure in the waste bottles causing them

to burst. Also if the solution is mixed very peroxide rich, one can make unstable compounds. Therefore, if you wish to use this mixture please make sure you mix only a minimum of the quantities you can live with.

Chlorinated Solvents
Chlorinated solvents (chlorobenzene, trichloroethylene, and methylene chloride) are used in various resist processes. They are particularly bad for you, causing cancer, organ damage, etc. They should not be mixed with normal solvents in waste bottles. There are separate waste bottles for chlorinated solvents. As with most solvents, they can be readily absorbed through the skin.

Glycol Ethers
Commercial photoresists and electron beam resists are dispersed in a variety of solvents. The composition of these mixtures is generally not disclosed on the bottle; you must look on the MSDS for it. One family of chemicals, the glycol ethers, commonly used in photoresists, masquerades under a variety of names. Most photoresists contain one or more of these as solvents.

Ethylene glycol mono methyl ether
2-methoxyethanol
Ethyl Cellosolve
2-ethoxyethanol (2EE)
Ethylene glycol mono ethyl ether
Ethylene glycol mono ethyl ether acetate
2-Ethyoxy ethyl acetate

Members of this family of chemicals have been shown to be teratogens and have other effects on reproduction in laboratory animals. A number of recent studies funded by IBM and others have found evidence that these chemicals can lead to miscarriage and other reproductive effects. To quote from the MSDS for AZ 2131 Thinner (2 Ethoxyethyl Acetate and N-Butyl Acetate).

"In studies with laboratory animals, 2-ethoyxethyl acetate caused birth defects, increased foetal death, delayed foetal development, caused blood effects, testicular damage and male infertility."

The liquid and vapour are eye and respiratory tract irritants and may cause kidney damage, narcosis, and paralysis (in simple terms, it damages your kidneys, eyes, lungs and brains). Primary routes of exposure are inhalation, skin absorption, and skin and eye contact with vapours. N-butyl Acetate, the other component of this thinner, has a similar list of possible systemic effects.

As with all chemicals, these are only the effects we know about. These experimental laboratory exposures were large amounts but nonetheless it is prudent to be careful with these solvents. If after reading this section, you still do not have sufficient respect for these chemicals, please go back and read it again.
Many users have become sloppy with resist.
Don't be.

If you can smell resist in the resist room, somebody is doing something wrong!! Find out what it is and stop it. Users may have resist on their lab coats or have placed resist-contaminated trash in the waste basket. This should be avoided.

The conclusion is that you should be careful with the use of even these seemingly innocent chemicals, wear the proper protective equipment, and work in a well ventilated area at all times.

Peroxides
All peroxides are highly oxidising materials. Considerable energy can be released in their reactions with common materials. Some peroxide compounds are unstable, and can explode.

We have hydrogen peroxide in the facility. Extreme care should be used in mixing solutions containing peroxides. Peroxides are incompatible with all forms of organic solvents and flammable materials.

First Aid Measures

In case of contact rinse affected area immediately with plenty of water while removing contaminated clothing etc.
If inhaled move to fresh air, if there is difficulty in breathing give artificial respiration or oxygen.
If swallowed wash out mouth with plenty of water provided the person is conscious.
Remove and wash contaminated clothing promptly.
Seek medical advice as appropriate.

Handling Of Compressed Air And Gases

Compressed air and gases must be treated with seriousness. These simple principles will help to minimise any danger of any incident.
Cylinders are normally of solid drawn steel and must be treated with care. They should not be subjected to shocks, falls, or undue heating.
Cylinders should always be stored upright. Grease and oil must not be allowed to come in contact with the cylinders. All cylinders must be treated as if full.

Cylinder valves should be opened slowly. Improvised tools must not be used for this purpose.

Always use two stage regulator on the gas cylinders i.e. with two gauges on the regulator, one showing cylinder pressure and the other outlet regulated pressure. Regulators should be used for gases for which they are intended and marked. Keep regulators in good shape and maintained order.
When connecting a regulator to a cylinder it is important that regulator connecting threads are aligned accurately. If threads are misaligned and forced to thread in it is possible to damage the regulator or cylinder head or both seriously.

Leaks sometimes occur between the regulator and cylinder. If a valve seat is leaking which is rare, a temporary measure is to attach a regulator to it and seek help from the concerned safety people. If a flammable gas is involved the cylinder should be immediately moved to a safe place (open area) , taking care to avoid possible sources of ignition.

Leaking cylinder must not be left on its own. If the leak is between cylinder valve and the regulator, which is most common, close the cylinder valve and attend to the connection between regulator and the cylinder valve. Ask for assistance as appropriate.
Connecting hoses should be of sound construction and of approved standard for the working pressure.

Handling Of Liquefied Gases

Handling of liquefied gases must be considered more hazardous than handling of liquid and solid materials. It is important that the hazardous properties of liquefied gases such as flammability, toxicity chemical activity and corrosive effects be well known. Every effort should be made to learn these various properties before the gas is put to use.
Liquefied gases has unique properties like pressure, high diffusion, low flash points (for flammable gases), low boiling points and in certain cases no visual and/or odour detection.

Hazard may arise as a result of equipment failure, leakage from systems and improper use of pressure controls.

- Diffusion of leaking gases may cause rapid contamination of atmosphere, giving rise to toxicity, anaesthetic effects, asphyxiation and rapid formation of explosive concentrations of flammable gases.
- The flash point of a flammable gas under pressure is always lower than the ambient therefore leaking gas can rapidly form an explosive mixture with air.
- Low boiling point materials can cause frostbite on contact with living tissue. This is common among the cryogenic liquids, such as liquid nitrogen, liquid oxygen and liquid air etc.
- Other effects of some liquefied gases are similar to hazards found with other chemicals e.g. corrosion, irritancy, and high reactivity.

Steps Necessary For Safe Working With Liquefied Gases

The procedures adopted for the safe handling of liquefied gases are mainly centred on containment of material to prevent its escape to the atmosphere and proper control of pressure and flow.

For the controlled removal of the liquefied gas a manual valve is used. It must be remembered that withdrawal of liquid must necessarily be done at the vapour pressure of the material. Any reduction of pressure will result in flashing of all or part of the liquid to gas phase, therefore leaking gas can rapidly form an explosive mixture with air.

Rapid removal of a gas from liquefied gas may cause the liquid to cool to rapidly causing the pressure and flow to drop the required level. In such cases cylinders (lecture bottles) may be placed in water bath to prevent drop in temperature of the cylinder.
Hazards of toxic, flammable and corrosive gases can be minimised by working in well ventilated areas. Where possible, work should be carried out in a extracted wet bench . Leaks should not be allowed to go unchecked.

Precautions Necessary In The Use Of Liquefied Gases

Cylinders that develop leaks should be treated as follows:

- Cylinder valve packing leaks can usually be corrected by tightening the valve packing nut. Clockwise for acidic gases and anti-clockwise for base gases viewed from above. If valve leak persist inform the supplier immediately. Remove the cylinder to a hood or location where the leakage cannot cause damage until the contents can be safely dealt with.
- On rare occasions emergency action may be necessary in order to move a leaking cylinder to a location where it can vent safely.

Cylinder Information

In the case of speciality gases valves to open and close cylinder are occasionally not equipped with hand wheel and require special cylinder key or wrenches to effect operation.
A valve packnut contains packing gland, packing around stem and it should not be tampered with. It may be tightened if a leak is observed.
A valve outlet is for connection to pressure or flow regulating equipment. Only use supplier or manufacturer's recommended gas regulating equipment.

Water Hose Connections

Water hose connections to the taps and the equipment and the condensers in reflux or distillation set up must be secured with hose clips which can withstand fluctuation of water pressure.

Safety Data Sheets

Safety data sheets are available *Dr Munir Ahmad* in room 707 and can be accessed via internet from, www.sigma-aldrich.com

For COSHH Purpose Chemicals Can Be Divided Into Subgroups According To Their Characteristics

One COSHH form can cover each category except high risk chemicals. This doesn't mean any chemical is exempt from COSHH assessment. It only allows you to add the new chemical to already completed COSHH form for that category. If not sure about any chemical please consult Dr Munir Ahmad.

General Solvents

Methanol, Ethanol, 2-Propanol (IPA), Acetone, Butanol, Butyl acetate, Ethyl acetate, Ethylene glycol, etc.

Hydrocarbons & Chlorinated Solvents

Toluene, Xylene, Hexane, Cyclohexane, Trichloroethylene, Dichloromethane, Chloroform, Carbon tetrachloride etc.

Acids

Sulphuric acid, Nitric acid, Hydrochloric acid, Acetic acid, Phosphoric acid, Oxalic acid, etc.

Bases

Sodium hydroxide, Potassium hydroxide, Ammonium hydroxide, Tetramethylammonium hydroxide (photo resist developer) etc.

Inorganic Chemicals

Copper sulphate, Nickel chloride, Calcium phosphate, Erbium chloride, Ytterbium chloride, Aluminium chloride,
Titanium isopropoxide, Zirconium propoxide, Silver nitrate, Potassium nitrate etc.

Organic Chemicals

Acetic anhydride, Urea, Pyrocatechol, Butoxyethanol, Cyclopentane, Dimethylbutane, Photoresist, N,N-Dimethylformamide, 1-Methyl-2-Pyrrolidinone, etc.

High Risk Chemicals

Cyanides, Mercury compounds, Lead compounds, Arsenic compounds, Cadmium compounds, Ethylenediamine, Hydrofluoric acid, etc.

CLEAN ROOM WORKING AND SAFETY

Clean rooms are a multi-user facility and they house a variety of expensive, delicate and precision equipment and chemicals which pose significant hazards if handled incorrectly. It is not possible to define a policy for every conceivable situation. Rules and policies are no substitute for common sense. Anyone who fails to act in a safe and responsible manner may be banned from further use of the clean rooms.

Clean rooms also operate under COSHH regulations. Any questions regarding your rights under the COSHH Lab Standard should be directed to *Dr Kristel Fobelets or Dr Munir Ahmad.*

General Procedures

User Orientation

An orientation and training process is required before any new user may work in clean rooms. An orientation session may be arranged with *Dr Munir Ahmad or Dr John Stagg*.

In general an individual is taken through the laboratory, discussing general rules, safety procedures, etc. This will follow an introduction to basics of the laboratory safety and chemical safety.
In addition to the initial orientation, training will be available for the use of specific equipment.

Clean Room Etiquette

To enter a clean room users must be properly attired. Users must follow a proper procedure for gowning in order to avoid generating unnecessary particles in the clean room. Unnecessary items may not be taken into the clean room. Shoes should be properly clean before using shoe covers.

A clean room also includes the changing room and service area attached to the clean room**.**

Clean Room Facilities

Special ventilation and air conditioning equipment is used to assure high level of cleanliness and temperature control in clean rooms. The supply and return are balanced to provide proper air flow and pressure for the room, therefore do not open and close service area doors unnecessarily. Housekeeping inside and service areas of clean rooms seriously limit the cleanliness level attainable in clean rooms.

The clean room is nominally Class 100; i.e., fewer than 100 particles larger than 0.5 micron per cubic foot of air.

Contamination Control

The primary limitation to clean room cleanliness is the people using the clean room. Your clothes, your feet, your skin, and your hair produce particulates which may compromise your research goals. By industrial standards, we have very lax clean room procedures. However, strict adherence to good housekeeping and common sense will allow us to maintain a level of cleanliness adequate for the types of work done in our group.

Approved Users

There is a variety of equipment for processing and analytical work in clean rooms. Most are complex and delicate. Each piece of equipment is under the charge of a staff member and or a designated member usually an RA. That designated member will train users on that instrument. When he/she is satisfied, the user will be authorised to use the system without further supervision.

This hands-on access is considered as an important part of the educational process. Each instrument necessarily has rules and operational procedures that are set by the staff to assure the continued and safe operation of the equipment. Violation of these procedures or carelessness in operation can result in damage to the equipment, down-time and considerable expense.

The wet chemical hoods may be treated as any other "instrument". You must familiarise yourself with the working of wet chemical hoods before you start using them. You are required to attend these sessions on chemical safety and chemical use prior to using any chemicals in the facility.

Equipment booking

Some of the equipment requires a booking in advance and depending on the demand, there may be a limit on the length of a session and the amount of time you may book in advance. All users are expected to adhere to the booking guidelines. For efficient use of equipment please cancel unneeded reservation. All projects require a certain process flow between instruments so one problem can throw off your entire process schedule. Also, sometimes a process can take longer than anticipated therefore please be flexible and cooperative with other users in stretching, sharing, and relinquishing time slots.

Visitors and Guests

You are discouraged from taking casual visitors in the clean room. All approved visitors using any equipment or laboratory facility must be booked into the **visitor's book available with Dr Munir Ahmad (Room 707)** and escorted and coordinated by the host with other users to avoid conflict for resources. You are also responsible for the actions and safety of your visitors and guests.

Problems

Problems with equipment malfunctions, breakage, etc. should be reported to

Dr Tom Tate (ext 46208)
Dr Munir Ahmad (ext 46260)
Dr John Stagg (ext 46260) or
the RA responsible for that piece of equipment.

Please do not try to fix or adjust anything, you are not responsible for, as most of the equipment is expensive and much of it is delicate. Considerable damage can be done at a great cost of both money and downtime by careless attempts to fix things. There is no reason for any one to use a tool on anything, which he or she is not responsible.

Chemical Bench Operation

The wet chemical benches inside Wolfson clean room are not like the extracted wet benches in the chemical laboratory. They are designed firstly to be clean benches, with laminar air flow, with only secondary consideration to ventilation and exhaust.

The air flow is such that when improperly used a considerable amount of fumes can be blown into the room. First, you must work well inside the hood, away from the front edge or chemical fumes will be blown into the room. You must also not unnecessarily block the array of little holes in the work surface. They are the exhaust holes. This disturbs the airflow in the entire hood. If you are using the hoods properly, you should not be able to smell chemicals outside the wet benches.
Please keep the wet chemical hoods clean, neat, and dry, before and after use.

Common sense is the most valuable aid you have in working with chemicals. If you are unsure, either don't do it or ask Dr Munir Ahmad or Dr Kristel Fobelets.

Ignorance of rules, lack of common sense, language difficulties, carelessness, and haste are not adequate excuses for unsafe behaviour. Safety violations could mean a long delay in the project.

Storage space

A limited amount of storage space, mostly in the form of small drawers, is available in clean rooms, typically, one to two drawers are enough per researcher. These should be used for keeping only currently needed samples, masks, etc. Please do not store junk, old samples and masks, and everything you ever did since joining the group.

Declaration

Before you sign the declaration please make sure you have understood all aspects of laboratory and chemical safety and you are confident enough to use equipment and chemicals.

I have read the safety guide and familiarised myself with the laboratory, equipment and chemical safety issues and have acquired all the know-how and the necessary training for safe working in the laboratory. I shall adhere to all safety guideline and safe working practices during my laboratory work as explained to me during the orientation session and the COSHH assessment.

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