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1 Introduction

Myfab is a cooperative network of three cleanroom laboratories excelling in micro and nano fabrication. The network offers an extremely wide platform for both academic and commercial interests in Sweden, Europe and around the world.

The Myfab network includes:

Ångström Microstructure Laboratory at Uppsala University

Electrum Laboratory at KTH in Kista

Nanofabrication Laboratory at MC2, Chalmers in Göteborg

Operated as an open user facility, the reliability and quality of the Myfab network heavily rely on the actions and behavior of its users. As a user at one or several Myfab laboratories you have a responsibility for the safety, work conditions and success of others. This responsibility starts with the contents of this document (including relevant appendices) which must be known and complied with at all times.

The Myfab laboratories offer 4 540 m^2 of cleanroom area and more than 430 tools for the fabrication and analysis of structures with dimensions in the micro or nanometer range. This environment requires that all users have sufficient knowledge on how to behave and act in our cleanrooms.

This document can be considered as a general instruction manual on the basic usage and safety aspects common to all of the cleanroom laboratories in the Myfab network. Primarily it regards the safety and work conditions, but also the technical design and maintenance of the cleanrooms. It also describes the potential dangers and general information connected with the usage of the cleanroom. The document is applicable in equal respect for all laboratory employees, as well as temporary and long-term guests. It governs the safety as well as the rules which must be followed for admittance and usage of the cleanrooms and tools**.** In addition to this general document, the three cleanroom laboratories in the Myfab network have their own site specific safety instructions and trainings in the appendices.

With this booklet, we want to document the pertinent aspects required for the general use of all the Myfab cleanrooms. To define a complete framework for all possible situations is impossible, but with the help of this manual, we are trying to address and describe the most important aspects.

Anyone who violates the lab usage or safety regulations, or in any way exposes himself/herself or others to danger, will be denied access to the laboratory by the decision of the executive management.

2 Cleanroom

2.1 Why cleanroom?

What is a cleanroom and why are they used in semiconductor factories?

Manufacturing of structures and devices with critical dimension in the micrometer (10^{-6} m) to nanometer (10^{-9} m) range puts very tough demands on the fabrication environment, in order to assure reasonable yield figures. The demands on the environment could be formulated in terms of contamination reduction, where we use an extended definition of contaminants, formulated as "A substance or a condition occurring at the wrong place at the wrong moment". Hence a contaminant could be, e.g,

- Particles (dead or viable)
- Chemicals (toxic, reactive, explosive...)
- Vibrations
- Static electricity
- Noise
- Radiation (electromagnetic, radioactive)
- Magnetic fields
- Climate (temperature, humidity, pressure)

Figure 1 SEM picture of a particle

The cleanroom provides an environment featuring contamination control in a broad sense. Our cleanrooms are designed to keep the most damaging contaminants at a low level. We will here discuss a few of those. When we refer to a cleanroom, it is a cleanroom for semiconductor manufacturing, keeping in mind that there are cleanrooms optimized for other purposes, which hence obey other design rules.

2.2 Particle control

Small structures fabricated in the fields of microelectronics, photonics or MEMS, are all sensitive to submicron particles (and greater particles). Particles adhering to wafers during specific process steps may reduce yield, affect the performance of the device, or do damage in other ways. Any particle at a size comparable to or larger than the critical dimension of the device or structure is bad for the yield. Especially critical are photolithography steps, where the presence of a particle on a mask will be reproduced to all wafers fabricated. A classification of particulate contaminants is shown in Figure 2.

Approximately 75% of all particles in a cleanroom come from the people working there. The remaining particles are generated from ventilation, room furniture and tools. Humans can generate more than 100 000 particles per minute at rest, and more than 1 000 000 particles per minute when walking. Particles can be inorganic or organic solids like dust, fibers, pollen, etc, but also viable particles like bacteria, mold or fungus. Aerosols are also particles in a cleanroom context. Examples are saliva emitted during sneezing or oil mist.

Particulate contaminants

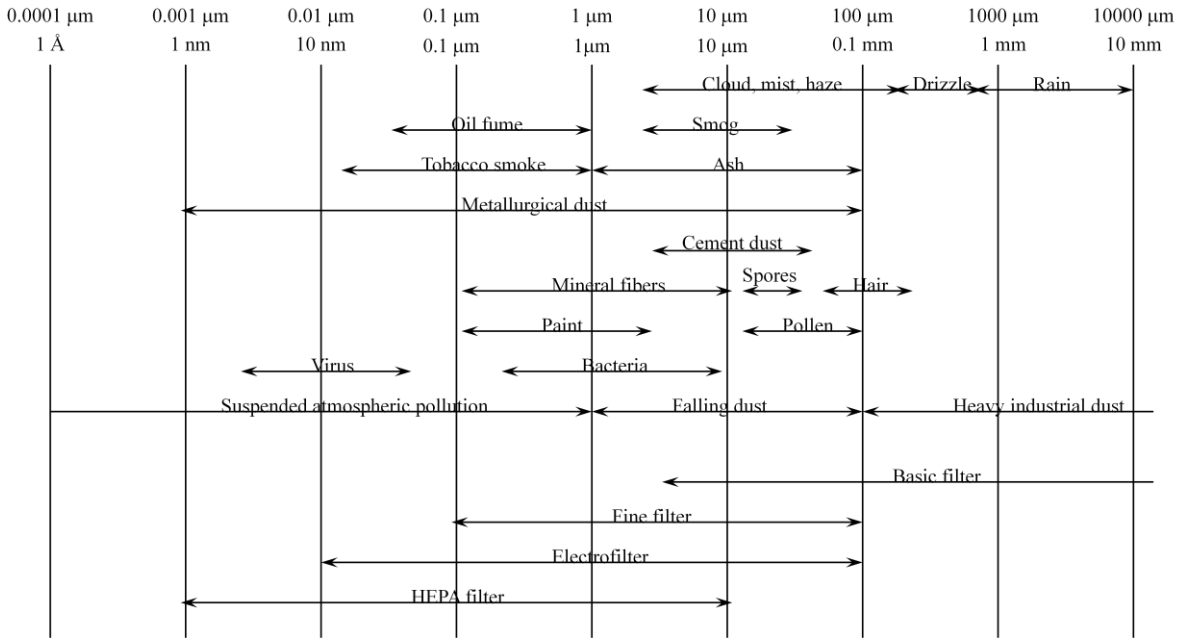


Figure 2 Particle size classification

2.3 Cleanroom behavior

In order to limit the number of particles in the cleanroom, cleanroom garments, which trap and hold the particles emitted by the human body, will be used. A correctly used outfit helps to drastically reduce the spreading of particles, but each user is also responsible for further reduction of particle generation and spreading.

Figure 3shows particle levels (per feet^3) in a walking area near the entrance to a cleanroom. The low levels in the beginning show the time when nobody is in the cleanroom. At around 10 o'clock some activity is starting in the cleanroom and the particle levels start to rise.

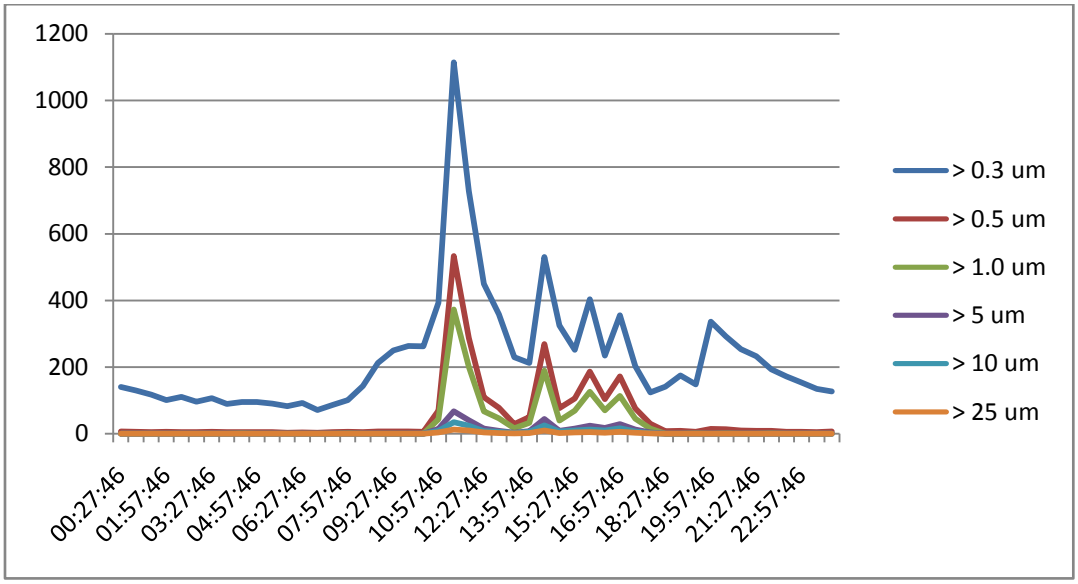


Figure 3 Particle level diagram

Every person generates particles. A person walking at normal pace will generate around 5 million particles per minute! In order to limit the number of particles spread to the cleanroom, special garments are used. These garments act as particle filters between the lab user and the cleanroom.

Activity	**Particle generation (> 0.5 µm/minute)**
Sit or stand without motion	100 000
Sit, small arm or head motions	500 000
Sit, arm-, leg or head motions	1 000 000
Rise up	2 500 000
Slow walk	5 000 000
Medium slow walk	7 500 000
Fast walk	10 000 000
Gymnastics	25 000 000

People – the predominant particle source

The cleanroom garment is a particle filter worn to protect the cleanroom environment from the contaminations coming from the human body. The filtering function will only work properly if the garments are worn correctly and are free from moisture and stains. It is also important to choose garments of correct size.

The garment is a particle filter and is not designed to withstand chemicals. The use of appropriate personal protection equipment (e.g chemical resistant gloves and eye protection) is compulsory when you work with chemicals. Please note that the cleanroom garments are expensive and that it is important to be careful and avoid contaminating them.

2.4 Cleanroom principles

The cleanroom is designed and operated so that the introduction, generation, and retention of particles inside the cleanroom is minimized. In Figure 4 you can see a cross section of a cleanroom design.

The addition of particles to the cleanroom is mainly limited by air filtering. A cleanroom cannot be cleaner than the air entering it. Ventilation control and air filtering ultimately determines the lowest achievable particle concentration levels in the cleanroom.

People also introduce particles to the cleanroom when they enter, as do the items they bring with them. By entering through airlocks and dressing into cleanroom garments such as hood, mouth cover, gloves, cover boots and coveralls, particle introduction is reduced. Correct procedures for dressing into cleanroom garment, the cleaning of items, etc., will also improve cleanliness.

Particle generation inside the cleanroom is suppressed by the use of cleanroom garment, the exclusion of particle generating materials, correct working procedures, etc. Common materials such as paper, pencils, and fabrics made from natural fibers are often excluded; instead they are replaced by cleanroom compatible versions. Cleanrooms for microelectronic purposes are not necessarily sterile (i.e., free of uncontrolled microbes) and more attention is given to airborne particles.

Retention of particles is suppressed by dilution of the cleanroom environment with recycled filtered air flushed in a unidirectional air flow and by cleaning of the cleanroom.

Desired set points for temperature, humidity, and pressure are maintained in the cleanroom through ventilation control.

Since photosensitive chemicals are used in photolitography, parts of the visible light spectra must be excluded from photolitography areas. This is achieved by using yellow fluorescent lamps and covering any windows with yellow transparent film.

The cleanroom properties of the Myfab cleanrooms together with a suitable distribution of various media, e.g. process gases, compressed air and DI water, exhaust ventilation for toxic and/or corrosive gases or fumes, drain for acidic wastewater and organic solvents are common to all Myfab cleanrooms.

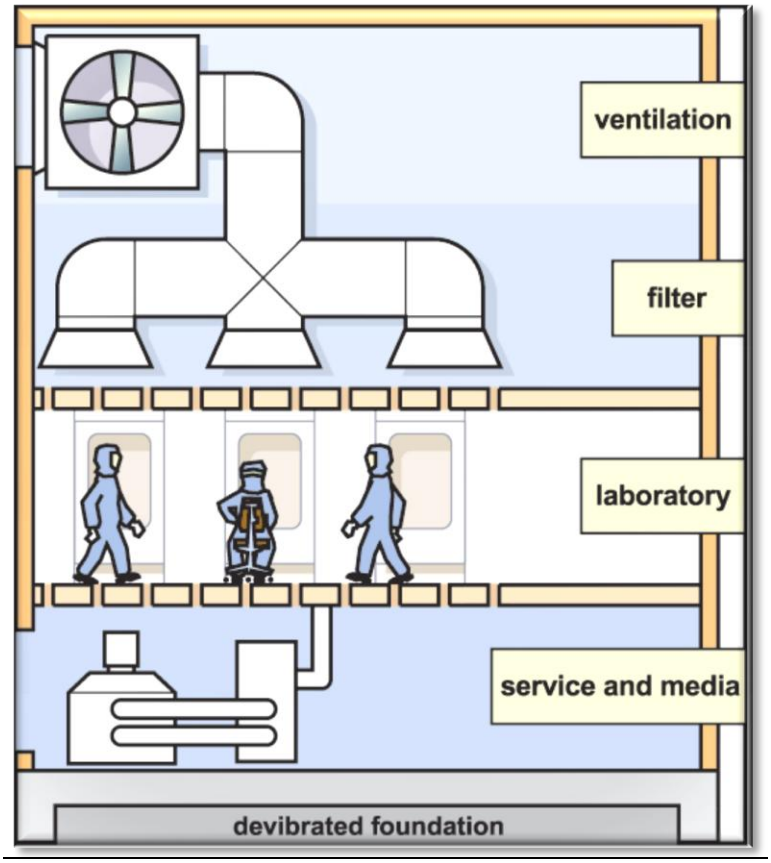


Figure 4 Cross section of a cleanroom

2.5 Cleanroom classifications

Cleanrooms are classified according to the number and size of particles permitted per volume of air. The old standard, US FED STD 209E, referred to the number of particles of size 0.5 µm or larger, permitted per cubic foot of air.

The new standard ISO 14644-1, specify the decimal logarithm of the number of particles of a certain size or larger permitted per cubic meter of air. So, for example, an ISO class 5 cleanroom has at most 10^5 = 100 000 particles per m³ of the considered particle sizes.

Both US FED STD 209E and ISO 14644-1 assume log-log relationships between particle size and particle concentration. For that reason, there is no such thing as a "zero" particle concentration. The table locations without entries are N/A ("not applicable") combinations of particle sizes and cleanliness classes, and should not be read as zero.

Because 1 m³ is approximately 35 ft³, the two standards are fairly equivalent when measuring 0.5 µm particles, although the testing standards differ. Ordinary room air is approximately class 1,000,000 or ISO 9. US FED STD 209E was officially cancelled by the General Services Administration of the US Department of Commerce November 29, 2001, but is still widely used.

Class	maximum particles/ft³					ISO equivalent
	≥0.1 µm	≥0.2 µm	≥0.3 µm	≥0.5 µm	≥5 µm	
1	35	7	3	1		ISO 3
10	350	75	30	10		ISO 4
100		750	300	100		ISO 5
1 000				1 000	7	ISO 6
10 000				10 000	70	ISO 7
100 000				100 000	700	ISO 8

US FED STD 209E cleanroom standards

Class	maximum particles/m³						FED STD 209E equivalent
	≥0.1 µm	≥0.2 µm	≥0.3 µm	≥0.5 µm	≥1 µm	≥5 µm	
ISO 1	10	2					
ISO 2	100	24	10	4			
ISO 3	1 000	237	102	35	8		Class 1
ISO 4	10 000	2 370	1 020	352	83		Class 10
ISO 5	100 000	23 700	10 200	3 520	832	29	Class 100
ISO 6	1 000 000	237 000	102 000	35 200	8 320	293	Class 1 000
ISO 7				352 000	83 200	2 930	Class 10 000
ISO 8				3 520 000	832 000	29 300	Class 100 000
ISO 9				35 200 000	8 320 000	293 000	Room air

ISO 14644-1 cleanroom standards

2.6 Ventilation

The overall ventilation system in most cleanrooms is comprised of three parts: Make-up-air (air entering a cleanroom from outside), air circulation and exhaust ventilation which is illustrated in Figure 5.

Circulation fan units (see Figure 6) supply air to the cleanroom through high efficiency particulate air filters (HEPA-filter) or ultra low penetration air filters (ULPA-filter). The filters are positioned in the cleanroom ceiling, and remove a large fraction of the particles in the air flow passing them. ULPA-filters have a higher efficiency than HEPA-filters. Typically the efficiency of a filter is specified at the particle size where the efficiency has a minimum. The specification for a HEPA-filter is the removal of at least 99.97% of all particles at size 0.3 µm. For ULPA the specification is 99.999% at size 0.12 µm . Air is drawn from the cleanroom to the suction side of the circulation fan units, where it is temperature regulated and pre-filtered before recycled back to the HEPA-filters.

Exhaust ventilation is used for applications where a protective environment is needed or where excess heat is generated. Examples are fume hoods, tools handling toxic or flammable gases, high temperature tools, etc. The exhaust ventilation system generally consists of one or several networks of ventilation ducts, which terminates at one or several exhaust fans. The exhaust fan expels the air to the ambient (possibly including a scrubber step, which is the removal or reduction of chemical discharge to the environment). There are often at least two separate exhaust systems; one made of corrosive resistant plastic (PVC or polypropylene) and one made of sheet metal (temperature resistant, non flammable, not attacked by organic solvents) see chapter 2.13 “Exhaust”.

Since the exhaust ventilation generates a net loss of air in the overall air recycling, make-up-air is required. Make-up-air is the addition of air-conditioned and pre-filtered air drawn from the ambient, to the recycling flow. Air-conditioned in this context means temperature and humidity controlled. This is illustrated in Figure 6. The make-up-air is added to the recycling flow in the circulation fan units (on the suction side, before the pre-filtering step). The amount of the make-up-air flow exceeds the total exhaust flow by the total leakage from the cleanroom to the ambient. During operation an overpressure is maintained inside the cleanroom. Depending on design, classification, etc., the overpressure may be in the range 5-40 Pa.

The necessary amount of the make-up-air flow is decided by the size of exhaust ventilation flow, and is independent of the recycled air flow. The amount of the exhaust ventilation flow is decided by the sum of the requirements for the different tools in the cleanroom.

The amount of the recycled air flow is decided by the total HEPA-filter area and the velocity of the air through the HEPA-filters. Desired velocity is typically 0.4 m/s. The total filter area may be expressed in terms of percentage filter coverage in relation to ceiling area or cleanroom footprint. These parameters are used to achieve the desired cleanroom class e.g. Class 100 : 300 air changes/hr, 30 % – 50 % air coverage.

$$air\ changes\ per\ hour\ = \frac{average\ air\ flow\ velocity\ \times\ room\ area\ \times\ 60\ min/hr}{room\ volume}$$

The make-up-air flow is often given as a percentage of the recycled air flow. From the above it is clear that this relation depends on the magnitude of filter coverage and the type and amount of machines installed. Greater percentage filter coverage and lower exhaust load, will give a small percentage make-up air. Lower percentage filter covering and higher exhaust load will increase the percentage make-up air.

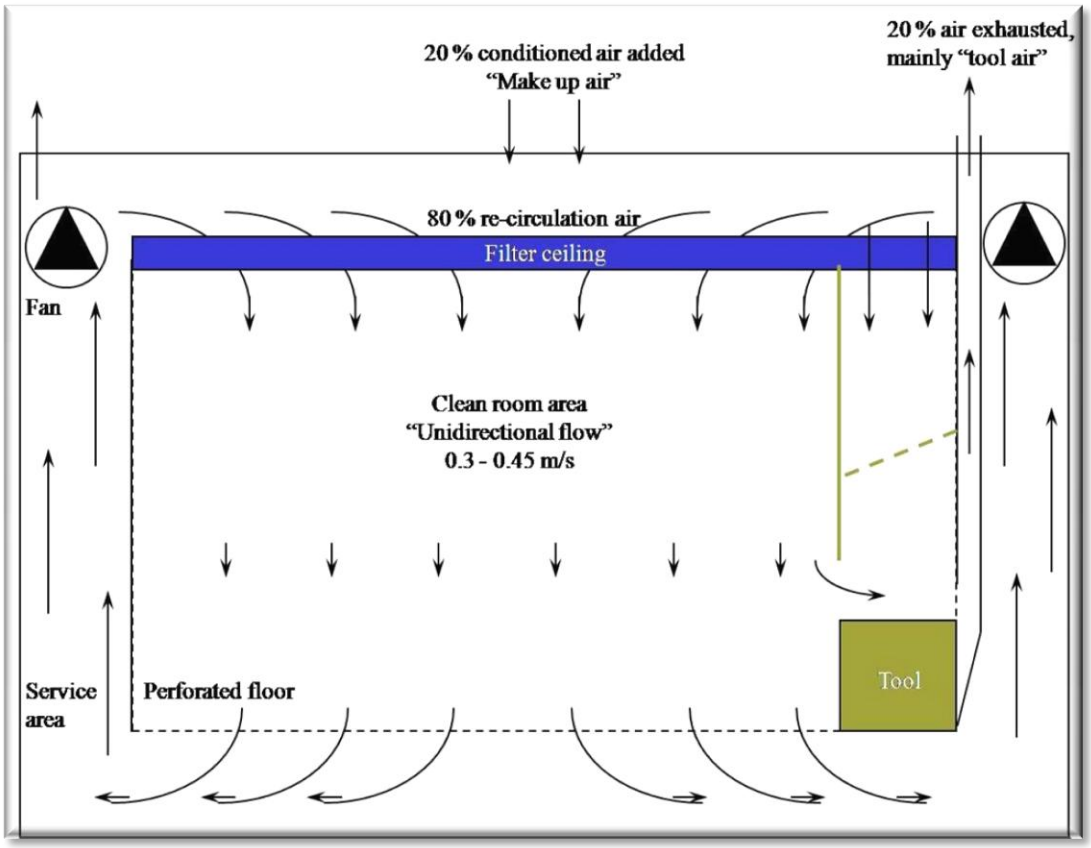


Figure 5 Example of air flow in cleanroom

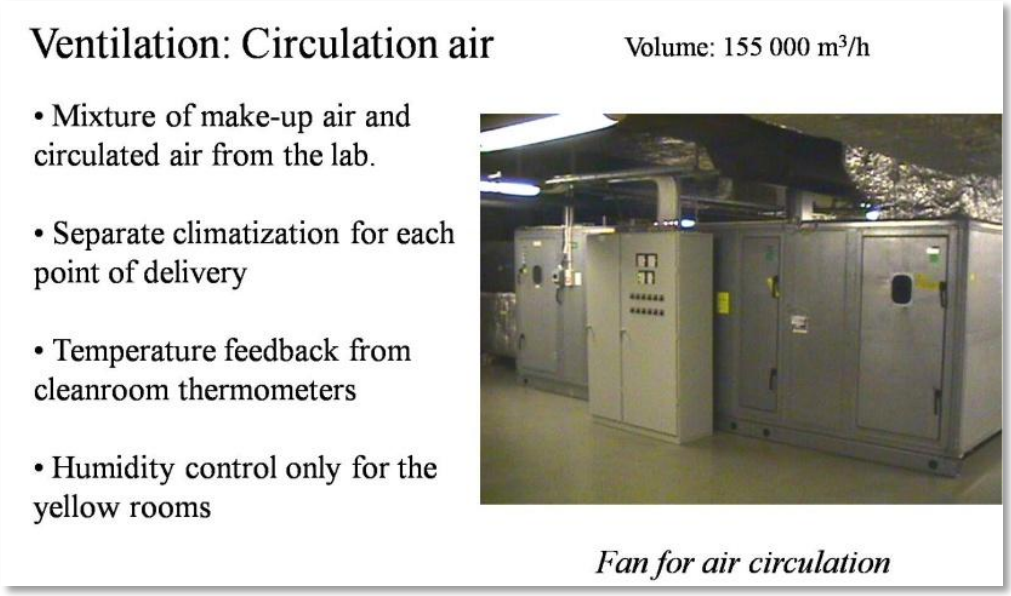


Figure 6 Example of air circulation fan

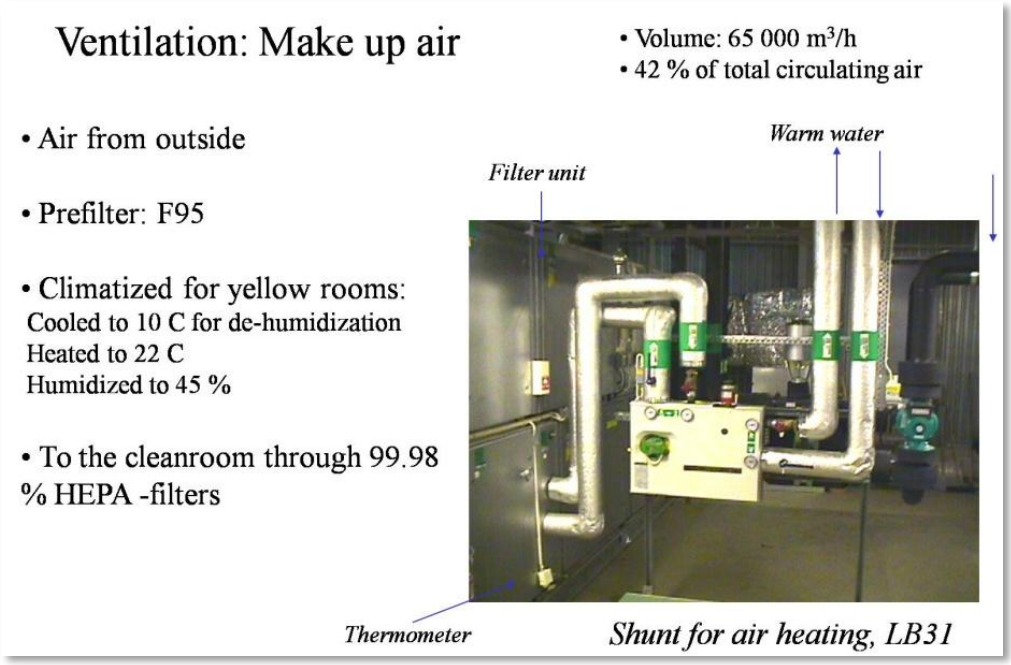


Figure 7 Make up air

2.7 Climate - Temperature and humidity

Temperature control of the cleanroom air is important for several reasons. One is the strong influence the temperature has on most chemical reaction rates, which becomes most evident in wet chemistry processes and the handling of resists and developers in lithography. Another aspect is the thermal expansion of materials, which might become influential in accurate dimension control over large distances, e.g. in stepper or e-beam lithography exposures. For this reason those tools are often equipped with special climate controlled chambers.

Accurate humidity control is fundamental for reproducibility in viscosity at spinning of photo and e-beam resists or polymers, due to the absorption of water. Some cleanroom climate control systems (HVAC- Heating, Ventilation and Air Condition) control the humidity to relatively low levels, such that extra precautions are necessary to prevent ESD electrostatic discharge problems. The ESD controls ("ionizers") are also used in rooms where ESD sensitive products are produced or handled.

In a photolitography area the desired temperature and humidity are slightly higher than in other areas of the cleanroom. The air supply to such areas is often equipped with more extensive air-conditioning systems, including active humidification.
It is also important that the temperature and humidity is kept at an appropriate level for the comfort of people working in the cleanroom.

2.8 Vibrations

Vibrations are especially harmful in processes where small structures are manufactured or inspected, e.g., in lithography exposure, electron microscopy, scanning probe techniques etc.

Vibrations are generally reduced by increasing the mass of the structure, in conjunction with soft damping and vibrational isolation. As the foundation conditions are unique for different construction sites, solutions for vibration reduction differ from facility to facility. Some ways to reduce the vibration rates are illustrated by the construction solutions chosen for of the cleanrooms in Stockholm, Uppsala and Göteborg.

In Stockholm the cleanroom is firmly settled on piles driven to the bedrock. Further, the cleanroom and other labs are placed on separate concrete slabs, standing on their own piles and vibrationally isolated from the rest of the building.

In Uppsala the piles did not reach down to the bedrock. Instead a “concrete rock” was formed by casting a substantial slab floating in the clay, to which the cleanroom was fixed. The cleanroom is isolated from the rest of the building.

In Göteborg the cleanroom was built using 48 soft steel pillars bolted to the bedrock, and with a separate foundation for the surrounding building. However, the cleanroom did not fulfill the specs in the low frequency spectra at start. This was solved by introducing steel cantilevers to stiff up the structure, with polymeric dampers in the fixtures to reduce the vibrations. The cleanroom is also isolated from the rest of the building.

2.9 Static electricity and ESD

Differences in electric potential between two objects may lead to an electric current, when the objects come in contact, or a spark, when they come close. These currents or sparks – Electro Static Discharge (ESD) – may cause severe damage to e.g., electronic devices, and cautions should be taken to reduce the probability to build up electric potential differences. This is made by grounding material, tools and workers in the laboratory.

Floor, walls and ceiling should be made in a conducting material, and all surfaces and tools should ideally be grounded to the same electric potential. Workers should wear garments made of a fabric woven with conducting fibers, and should in some cases ground themselves by applying a grounded wrist strap before working with sensitive devices. The wrist strap is connected to ground through a large resistor, allowing the charges to leak slowly, thus preventing an electric discharge. Some work-tables in the lab are covered with ESD mats, made of a material which also slowly leads charges to ground. ESD straps and mats are often connected to a measurement console, indicating if any hazardous rest potential or charges are present.

By increasing humidity in the room, the moisture may dissipate electric charges. A similar effect is given by ion generators, ionizing the air, which will neutralize charges accumulated at insulating surfaces.

2.10 General media

House gases, chemical drains, exhaust systems, electrical power, cooling water (Figure 8) and ultra-pure water (Figure 8), compressed air, tool vacuum, liquid nitrogen and central vacuum cleaning, are media common to the Myfab labs (and most microelectronic cleanrooms).

Figure 8 Distribution of cooling water

Figure 9 Water supply to the cleanroom

2.11 House gases

A gas that is delivered through a piping system (Figure 10) to several utilization points in the facility, from one gas bottle or tank installation, is a house gas. Common to the Myfab labs is the distribution of nitrogen (N_2), oxygen (O_2) and argon (Ar) from a supply storage located exterior to the main building housing the cleanroom.

Nitrogen is used as process gas, technical gas (dry pumps, shaft purge in spinners, etc.) or for blowguns, rinser/dryer, etc. The purity requirements on the nitrogen may differ from application to application, why parallel nitrogen lines with different purity are common. The nitrogen is drawn from a cryogenic tank with liquid nitrogen, fed through evaporators and then delivered to the cleanroom. Depending on purity requirements, in-line filters and getter purifiers are installed on the lines.

Oxygen is used as a process gas in dry etchers, oxidation furnaces, etc. For any facility with moderate consumption, the oxygen is drawn from gas bottle.

Argon is used typically in dry etchers and sputters, or in other processes where nitrogen is not inert. The installation can be a gas bottle or cryogenic tank, depending on the magnitude of consumption.

In addition to the gases above, other house gases may be installed, depending on the activities and needs in the cleanroom. Not uncommon house gases are hydrogen (for wet oxidation, and epitaxy processes), silane (silicon precursor in deposition processes) and helium (technical gas and more seldom process gas).

Figure 10 Gas distribution

Figure 11 Gas panel

2.12 Special gases

Special gases are tool specific, or locally installed, process gases. The name also refers to a market segment within the gas industry aimed at the microelectronics industry, usually with high requirements on purity.

A typical installation contains the gas bottle connected to a gas panel (Figure 10), which is located in an exhaust ventilated gas cabinet. The gas cabinet may be located in the service and media area, a dedicated storage building adjacent to the main building or in the grey area behind the tool, depending on cleanroom design and requirements on line length.

Most special gases are either etchant gases, or precursor gases for elements in deposition processes.

Note! Operating valves or other components on gas installations is generally forbidden. *The only exception is for trained service personnel and licensed users of a specific tool, if that is stipulated in the operating instructions of that tool.*

2.13 Drain

There are two drain systems installed in the labs, solvent drains and acid drains. The solvent waste is collected via stainless pipings into a stainless steel tank. Waste water in the acid drain is passed through a pH neutralization facility, before being expelled to the public sewer.

All process benches and all fume hoods are connected to the proper waste drain. If you have waste chemicals and you are unsure about what to do with them, please contact the lab personnel for advice. Never discharge any materials in the drains if you are not sure it belongs there. Put it in a closed bottle so you can decide later. Some chemicals should always be collected in waste bottles after use, to be disposed of by the lab personnel.

- **The acid drain tubing is fabricated in plastic, why draining of hot baths should be avoided. Consult local regulations for procedures and temperature limits.**
- **In fume hoods with both acid and solvent drain there is a risk of draining acid into the solvent drain, by mistake.** *This will corrode the welding in the solvent tank, eventually leading to costly repairs. A greater volume oxidizing acid (sulfuric or nitric acid) may also start a violent reaction in the solvent tank.*
- **The chemical wastes which are left for further destruction should be labelled and identified by full name of the chemical(s), concentrations, hazard symbol and name of user.**

2.14 Exhaust

All Myfab labs have two or more separate exhaust ventilation systems. One system for corrosive applications made of plastic is shown in Figure 13. The other system is made of sheet metal, for applications that are non-corrosive and work at high temperatures, uses flammable gases or organic solvents, shown in Figure 12. Some tools are connected to the toxic exhaust shown in Figure 14.

Failure of an exhaust fan will turn the cleanroom into an unsafe work environment. Any sign of low capacity or failure on the exhaust must be reported to lab staff. Tools that require exhaust and are fitted with alarms or interlocks, must not be tampered with and operated despite any indication of exhaust failure.

The exhaust fans are powered by a back-up diesel powered generator in case of a power failure.

The main exhaust flow is through the fume hoods, wet benches and tools using toxic or flammable gases often at high temperature (Metalorganic vapour phase epitaxy (MOVPE), Low pressure chemical vapor deposition (LPCVD), etc).

Some labs have automated distribution of the exhaust capacity to utilization points where the capacity is needed at the moment, other have static fixed positions on the dampers. Regardless, the exhaust capacity has an upper limit. Fume hoods, lids to chemical baths in wet benches, doors to exhaust

- **The exhaust ventilation is a critical feature of the infrastructure.**
- **The degree of automatic control of dampers on the exhaust ducts differ between the Myfab labs.**

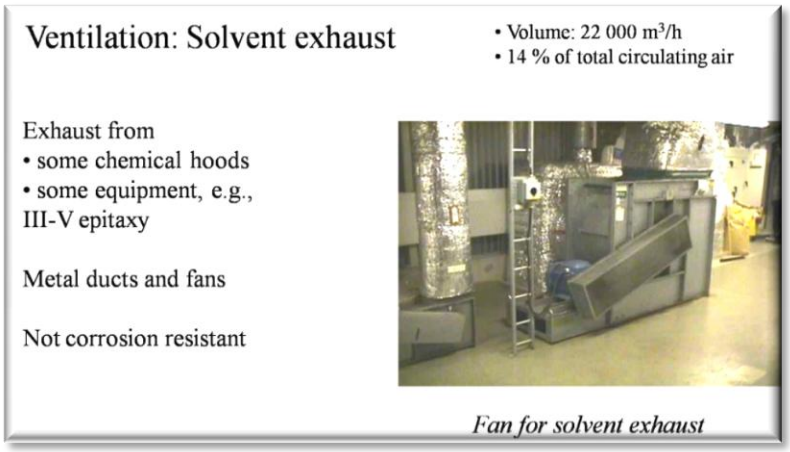


Figure 12 solvent exhaust fan

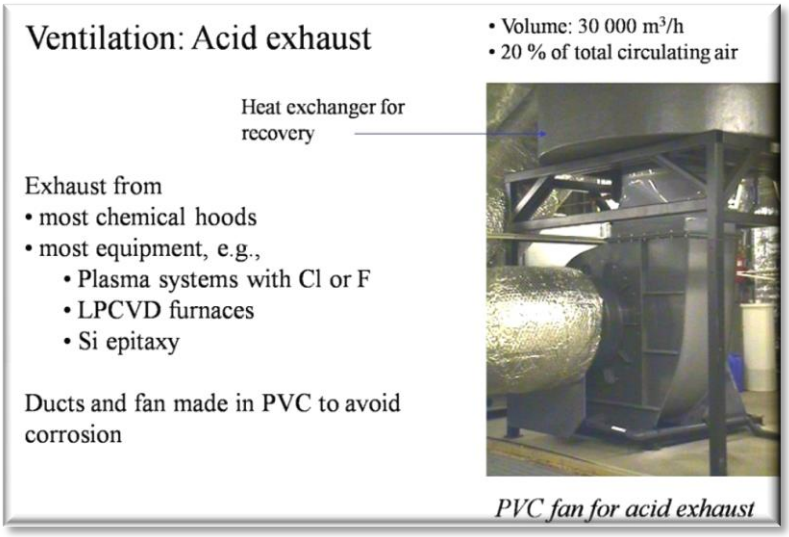


Figure 13 acid exhaust fan

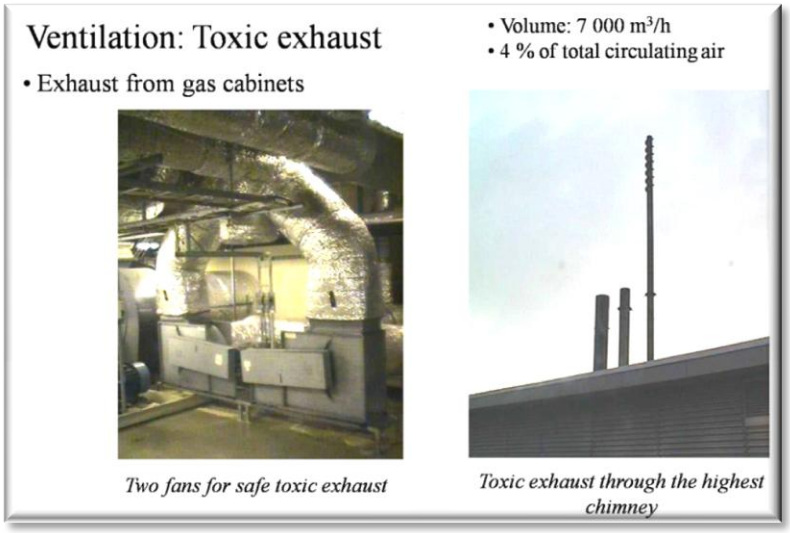


Figure 14 toxic exhaust fans

2.15 Electrical power

The cleanroom uses a large amount of electrical power (Figure 15). The main consumers of electricity in a cleanroom are the ventilation system for the cleanroom itself and some process tools, like the furnaces.

If a power failure occurs, diesel powered emergency generator will ensure that important systems have power, such as: exhaust systems, sensors for toxic or hazardous materials and alarm systems. The emergency power is NOT capable of supplying power so that tools are able to continue the process, except for shutting down the process to a safe state. Some tools have an UPS (uninterrupted power supply) system for a safe shut down, e.g. E-beam lithography tool.

Figure 15 Distribution of electricity

2.16 De-ionized (DI) water

De-ionized water is available at almost all process benches.

De-ionized water which is also known as de-mineralized water is water that has had its mineral ions removed, such as cations from sodium, calcium, iron, copper and anions such as chloride and bromide. Removal of ions causes resistivity of water to increase, providing a convenient measurement for the exact extent of deionization. Ultrapure deionized water has a theoretical maximum resistivity of 18.31 MΩcm. Cleanroom processes require large amounts of DI-water (>18 MΩcm) and there is therefore a water tank in the media basement.

In addition to processing, this water is also used in large amounts to humidify the air that is supplied to the cleanroom during the colder parts of the year.

The DI-water is distributed through a loop through the cleanroom so no water is standing still to minimize the possibility of bacteria growth and particle generation. From this loop DI-water is drawn at the various points of use. A particle filter in the loop reduces the particle levels.

Even though it is possible to get this ultra-pure water just by simply opening the tap, it does not mean that it is free or that the source is unlimited. Even if some processes require extensive and careful rinsing, you are asked to ensure that no water taps are left open or that rinsing baths are left flowing unnecessarily. The purification system for DI- water is illustrated in Figure 16.

De-ionized water is provided for fabrication process purposes only. It is not considered as potable water, and must not be ingested.

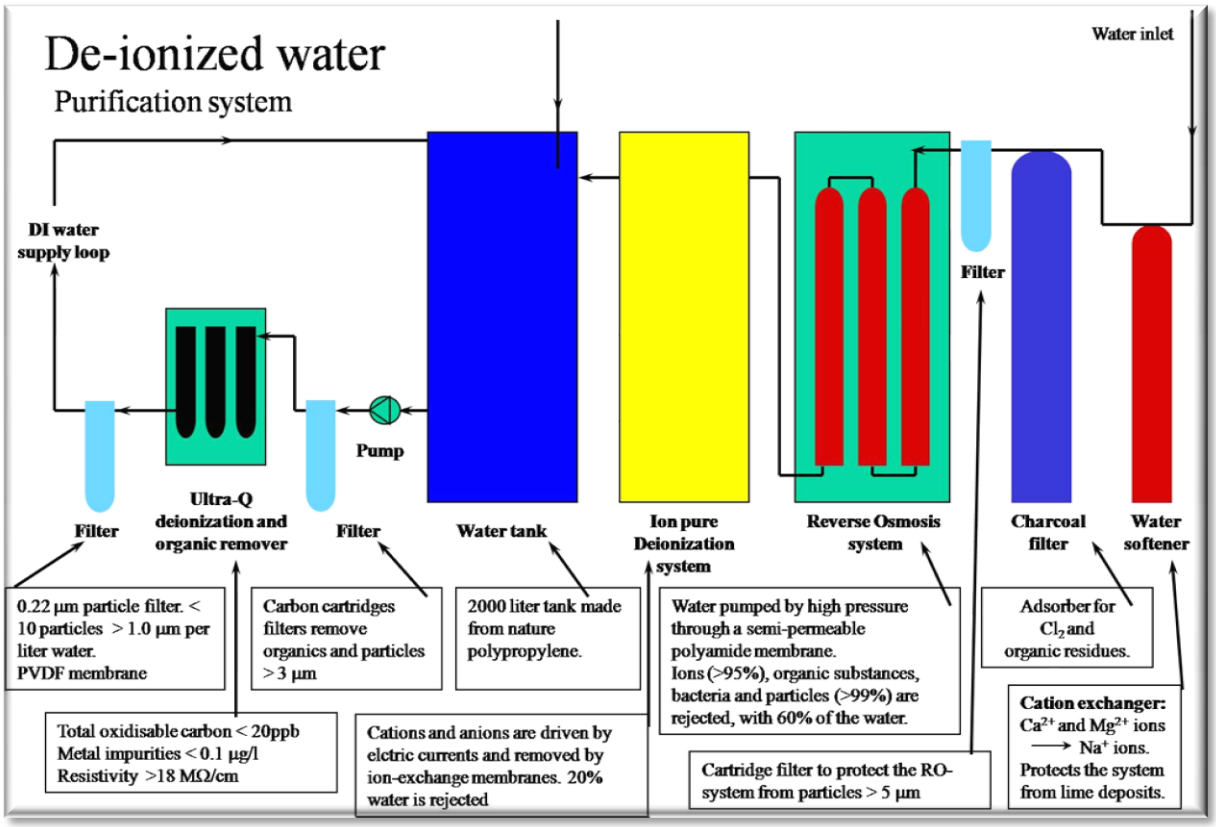


Figure 16 Principle of a DI purification system

2.17 Compressed dry air, vacuum, liquid nitrogen

Compressed Dry Air (CDA) is used only for pneumatic valves and safety functions at the process benches. Tool vacuum is used for spinners, chucks, and vacuum tweezers, etc. Vacuum cleaning in the labs utilizes a central vacuum cleaning (CVC) system. It is used for general house cleaning, (cautious) cleanup after broken wafers in tools, as well as an integral part of some LCD processes. Please note that the CVC system should not be used for chemical spills, as the hardware is not designed for chemical exposure.

In some cases liquid nitrogen (LN_2) are needed for cooling purposes. Liquid nitrogen is extremely cold, 77K (-196°C) and may cause severe damages by freezing of the skin and underlying tissue. It is especially dangerous if LN_2 is spilled into a closed volume, such as the inside of your shoes or gloves, or splashed into your eyes. LN_2 is available for users in some laboratories (see local conditions). Figure 17 is a example of a liquid nitrogen tank.

Only Dewar vessels may be used due to the large evaporation rate from open containers. You must watch the filling process continuously to avoid overfilling. When handling large amounts of LN_2 indoors, there is always a risk of suffocation as the evaporated nitrogen may replace the oxygen if the room is small or if the ventilation is insufficient. Large spills must always be avoided, as 1 liter of LN_2 will turn into more than 700 liters of gas when evaporated. Large spills will also cause severe damage to the floor.

Our supplier of LN_2 monitors the tank levels remotely, and delivers new LN_2 when needed. The nitrogen is not free of charge. We use large quantities every year for venting, purging, etc. Don't waste nitrogen by using excessive flow rates or venting

Figure 17 Liquid Nitrogen tank

2.18 Entry and Exit to the cleanroom

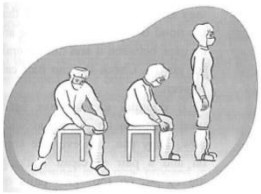
The best method of changing into cleanroom garments is one that minimizes contamination getting onto the outside of the garments. One such method is described below, and assumes that a facemask, hood, coverall and overboots are used. It requires that the garments are put on from the top down. Some of the suggested procedures may be unnecessary in lower classes of cleanrooms, and further procedures can be introduced in cleanrooms that manufacture products very susceptible to contamination.

Sticky cleanroom mats or flooring are often used in the approach to the change room. They work by removing dirt from the soles of footwear as personnel walk over them. Make sure you take several steps on the sticky mat and don't walk around it.

1. Personnel should remove sufficient street or factory clothes to feel comfortable in the cleanroom that typically has a strictly controlled environment. Generally speaking most users prefer to have light clothing underneath the coverall when working in the cleanroom, but this is a personal preference.
2. Watches and rings should be removed. They can harbor dirt, produce chemical and particle contamination, and are liable to tear gloves. Rings that are smooth may be kept on if the ring (and under the ring) is kept clean.
3. Select the garments to be worn and check the size and that the packaging is free from tears and faulty heat seals.
4. Cross over from the pre-entry area into the change zone. The demarcation between these two zones may be a line on the floor, door or a crossover bench, or both. If a bench is used footwear should be attended to as it is crossed. If a bench is not used, then a cleanroom mat or flooring should be used. Personnel should stop at the mat and put their footwear three times to the mat, to make certain that it is clean and the minimum of contamination is tracked into the next zone.
5. A facemask (if required) and hood is put on, the hair must be tucked in and the studs, snaps or ties at the back of the hood are adjusted for comfort.
6. If a hand washing system is installed in this area then the hands should now be washed. This is possibly the best time for personnel to wash their hands as clean garments will now be handled and contaminated parts of the body, such as the hair and face, should not be touched again.
7. The coverall should be removed from its packaging, unfolded and put on without touching the floor. There are several methods of putting on the garment to ensure that it does not touch the floor but we will only describe one:

   The coverall can be gathered together at the 4 corners i.e. the two wrists and the two ankles. It should then be possible to put first one leg and then the other into the garment without the trousers legs touching the floor. See picture.

8. Personnel should sit on a bench in order to correctly put on the cleanroom footwear (overboots). While still sitting on the bench, the legs of the cleanroom garment and the footwear should be adjusted for comfort and security.



9. If required, protective goggles can now be put on (or when entering the cleanroom). These used not only for safety reasons but to prevent eyelashes and eyebrow hair falling onto the product.
10. The garments should be checked in a full-length mirror to see that they are worn correctly. Check that the hood is tucked in and there no gaps between it and the coverall. Check that no hair or hair net can be seen.
11. Low particle working gloves should now be put on, without the outside of them becoming contaminated. Make sure to grip the gloves at the edge of the cuff and not the top i.e. fingers.
12. Personnel may now proceed into the cleanroom.

2.19 Cleanroom rules

Please obey the following recommendations of proper cleanroom behavior:

Plan your work in the cleanroom well. Book tools and order chemicals in advance to avoid reentering the cleanroom.

Persons suffering from cold or eczema should not enter the cleanroom.

A good personal hygiene is a condition to enter the cleanroom.

Smokers should wait at least 30 minutes after smoking before entering the cleanroom. Smokers and snuff users have to rinse their mouth before entering the cleanroom. Snuff is strictly forbidden in the cleanroom.

Remove rings and wristwatches if they can damage the gloves or make openings in your garment.

- **No beverages or food, including chewing gum, are allowed in the cleanroom.**
- **Do not bring paper protocols in to the cleanroom.**
- **Do not bring pens or pencils (which are not cleanroom compatible) into the cleanroom.**
- **All movements should be slow and well planned.**
- **Avoid touching any clean surfaces, such as loading stations.**
- **Avoid creating crowds as contamination then will be concentrated.**
- **Do not scratch yourself through the garment, as this will cause increased particle generation.**
- **Avoid talking near your component/product.**
- **Do not carry items close to your body. Carry them high and in front of you.**
- **All components/products stored in the cleanroom have to be covered, preferably stored in closed boxes. Please note that long-term storage is not allowed in the cleanroom.**
- **Garments that are wet or stained have substantially reduced filtering effect and have to be exchanged immediately.**

When leaving a cleanroom, personnel shall discard their disposable items, such as mask and gloves, but reuse their hood, coverall, overboots etc. on re-entry. If the garments are not to be re-used, they should be placed in a separate container for dispatch to the cleanroom laundry. The garments are normally washed once a week.

If the garments are to be used again on re-entry, they should be removed so that the outside of the garment is contaminated as little as possible. The cleanroom footwear should be removed, one at a time, at a crossover bench. The coverall should than be unzipped and removed using the hands within the garment to remove it over the shoulder and down the waist. In a sitting position, one leg is now removed. The empty arm and leg of the garment should be held so that they do not touch the floor. The other leg can now be removed. The facemask and hood can now be removed. Garments so be used again should be stored on hangers to prevent contamination.

2.20 Cleaning the cleanroom

Why does a cleanroom need to be cleaned? For one, the cleanroom clothing does not stop dispersion, and a person can disperse, when wearing cleanroom clothing, over 100 000 particles/min (particles ≥ 0.5 µm). The tools also disperse millions of particles. Many of the larger particles will easily settle by gravity onto horizontal surfaces and smaller particles are thrown from the air stream onto surfaces. Dirt can also be brought into a cleanroom through foot-borne transfer. That's why cleanroom surfaces get dirty and must be cleaned otherwise the contamination is transmitted to the product. Cleanrooms can appear to be clean but can, in terms of cleanroom requirements be very dirty. The human eye will not see a particle smaller than 50 µm.

The main force that holds particles to the cleanroom surfaces is the London-van der Waal´s force, this being an inter-molecular force. Electrostatic forces can also attract particles to a surface, and depends on the type of materials used within the cleanroom. The methods that are generally used for cleaning a cleanroom are: vacuuming (wet or dry), wet wiping (mopping or damp wiping) and picking-up with a tacky roller.

The methods used to clean cleanrooms will vary according to the standard of cleanliness of the room and its layout. It's therefore necessary to tailor the cleaning method to the cleanroom and the following information may assist this.

- If you can see any dirt in a cleanroom it is neither a clean room nor a cleanroom and must be cleaned.
- Cleaning a cleanroom can generate many particles. To minimize contamination generated by the cleaning process the air conditioning should be fully on and your products well protected.
- Cleaning must be done slower than would be the case in the home, which will minimize the dispersion and ensure more efficient cleaning.
- Use overlapping strokes of the wiper (or a mop) never rub. A cleanroom will always appear clean to the eye and it is not easy to ensure that every piece of the surface is cleaned, except by an overlapping pass method.
- If a damp wiper is used then it should be folded, and as the cleaning proceeds it should be refolded to give a clean surface. After all surfaces of the wiper are used it should be replaced.
- If you want to damp the wiper, use tap water diluted isopropanol (IPA) 5% - 10%. Avoid using De-ionized (DI) water since it is aggressive (corrosive).
- All Myfab cleanrooms hire specially trained cleaning staff.

3 Administrative guidelines

All users of the cleanroom must attend a set of introductory lectures in order to get sufficient knowledge to be able to work safely and efficiently in the cleanroom. This education is given by the cleanroom staff. The course will cover the basics on cleanroom behavior, chemical safety, the emergency systems, such as how the alarms and evacuation plans are organized, the infrastructure of the cleanroom and administrative tools as LIMS.

3.1 Cleanroom access

After attending the training course, the user's keycard is activated for access to all cleanroom areas. As an active user at one of the Myfab sites you have the entire network at your disposal. A brief orientation about available resources can be obtained from the equipment list for each laboratory. Please note that an activated keycard does not mean free indiscriminant access to the lab tools.

3.1.1 General Access Conditions

Typical situations where there is a need to use resources at other sites could be that a requested tool is down for repair (backup) or that the required capability is not provided (complement) by the base laboratory. Whenever there is a need to use external resources, the first step should be to investigate the possibilities provided at other sites within the network. A first indication is given by the equipment lists (accessible through LIMS), but a more definite conclusion often requires a direct and in-depth discussion with the appropriate tool responsible engineer at the receiving site (see equipment list).

Resources outside your base node can be reached by on-site or remote access and any use of a secondary node within the Myfab network will be charged by the hour according to the common Myfab fee model. Whether the on-site or remote option is chosen, neither the fix (monthly) access fee nor any high cost reduction apply to lab sessions at secondary nodes.

3.1.2 On-Site Access

For extensive or repeated use of a secondary node, on-site access should normally be the preferred choice. In this case the user must be activated at this node; a request (e-mail) should be sent to the user administrator at the secondary node and the site specific user introduction should be scheduled in a timely manner. After activation the user can sign up for any relevant operator training to get the appropriate operator licences and to get access to the corresponding booking schedule. All education and training may be charged and regular tool usage is subject to the established Myfab fee table. It is evident that the required preparation and training sessions require some planning and a certain delay is therefore inevitable before an on-site access can be in operation.

3.1.3 Remote Access

For urgent (backup) or isolated activities, evaluation trials or standardised processing the remote access option should normally be recommended. In this case the work is done by a staff member at the secondary site and the user does not have to be active at this node. The user may choose to just specify the process and send the material to be processed, or to bring the material in person if personal presence on-site is considered important. In this case, however, the user can only enter the secondary lab as a visitor, escorted at all times. Remote processing is charged by the hour for tools as well as personnel.

A few processes have been standardised to a level which makes remote access very straightforward, e.g. optical mask generation and ion implantation.

3.2 LIMS

Tools may be booked through LIMS; a Laboratory Information Management System developed within the Myfab network. The LIMS is a platform for three laboratories; Electrum lab, MC2 nanofabrication lab and MSL Ångström lab.

To enter LIMS a username and password is required. These are normally given after participating in the Introduction course. You can also apply for access to LIMS and membership to a specific laboratory, by browsing to the LIMS webpage and entering the required information. Each user must be associated with a project which finances the activity in the lab. Each user is placed on an appropriate user level (user, project leader, project manager or administrator,)

When entering LIMS you will first see the main 3 menus of **Tools**, **User** and **Info**.

In "**Tools menu**" all information about tools such as booking rules, tool status, logs, personal and tool schedule is available. In the menu of *my licensed tools*, it is possible to make a reservation for a time on your licensed tools at *book*. At *view*, technical information as well as Standard Operating Procedures (SOP) is found. The tools are sorted in three groups of booking status; compulsory, optional and non-bookable kind. The lab buddy system for offering users to work at non office hours (6pm to 7 am) is different at the 3 sites, and can be used at *verify night shift booking*. For general booking rules see more below,

In "**User menu**" the user personal data is stored at *My Profile*, and should be updated with eg email address, telephone number etc by each user. You can also find contact information to all other users of the laboratories, as well as statistics of user tool bookings and sending messages for other lab users.

In "**Info menu**" you can find important information; *chemical list about chemical* used in the lab, as well as *tool documents* (SOP) and *general documents* of the lab maintenance.

3.3 Process tools

The cleanroom is equipped with a variety of advanced process tools. All process tools are listed and described in LIMS. For each processing tool in the cleanroom, there is a responsible person. The responsible person performs maintenance work, repairs, calibrations and other technical work concerning the operation of that tool. In order for a cleanroom user to be allowed to independently run any particular processing tool, the tool responsible person must issue a license. The license is preceded by an education on the tool. The education is given by either the tool responsible person, or by an instructor appointed by him, and varies in scope and length with the complexity of the tool. During the driving license session you will be informed about all practical details on the tool handling. After that the tool will be registered in your LIMS account for booking and use on your own. Follow the user instruction and recipes!

You should never touch any tool that you have not been trained for. In addition to the risk of damaging the tool, you also run the risk of hurting yourself! It is also important to know how the specific tool is used by others. It's important that you follow the tool instructions to assure the safety and quality.

Contamination in one piece of tool may easily spread and "cross-contaminate" a complete process line, and cause costly and time consuming service work. Special care regarding choice of materials is important when working with high temperature process steps, vacuum and plasma tools. Information about safety and cleaning of the tool is included in the user driver's license training.

Information about responsible person, instructors and licensed users for each tool, is displayed in LIMS. The license is only a permit to use the tool according to established recipes and standard procedures.

Please inform the responsible person immediately if you observe any damage or functionality problem of the equipment in use. It is up to each user to clean and reset the process tool after use.

- **We recommend new users to follow an already experienced user during some sessions of processing on the actual tool, before contacting the tool responsible person for license issuing.**
- **The fact that you have a license to use the tool does not mean that you are free to introduce any strange or non-approved materials without contacting and getting approval from the person responsible for the tool.**
- **It is strictly forbidden to perform any service work, or experimental processing, without first consulting the tool responsible person.**

Figure 18 Process tools

3.4 Rules for tool drivers license and booking

- Tools may only be operated by trained persons that are registered as licensed users in LIMS. If you want to use a specific tool, contact the tool responsible person or an instructor (also listed in LIMS).
- Completed training should always be announced to the person responsible for the tool (if different from instructor) who will approve the license and inform cleanroom staff for registration in the user-database LIMS.
- The person responsible for the tool can order additional training if tool rules are not obeyed.
- Each licensed user is mainly responsible for keeping himself/herself informed about tool and/or instruction changes which are announced via LIMS.
- It is recommended that users contact the person responsible in order to obtain updated information about tool and/or instruction changes if the user has not actively worked in the cleanroom during the preceding three months. Contact with the person responsible should always occur if the user is uncertain about the status or running of the machine.
- Users who have been away from the cleanroom for a period longer than twelve months should contact cleanroom staff to obtain an update in the lab security rules.
- All users removed from the database for a period longer than one year are treated as new users and are obliged to undergo appropriate training in order to obtain lab access and tool licenses.
- It is recommended that users be informed about changes regarding tool and/or instructions by the distribution of a short notice to all license holders registered in LIMS for the concerned tool.
- Never make your own installations, repair or modifications of the tool. Contact the tool responsible person or a service/process engineer for help.
- If you get problems with a process or an tool, contact the tool responsible person or a service/process engineer for help.
- It is absolutely forbidden to change any process related settings, or to run non-qualified processes on your own. Always contact the tool responsible person for approval first.
- Reserve tools only if you know that you are going to use it.
- Remove any reservation you are not going to use. Someone else might need the process time.
- If you are going to extend over the time limits of your reservation, first talk to the person signed up after you in the LIMS.
- If possible, ask before you unload others samples, and handle others belongings with care. Long process time is often invested in each sample.
- Always leave an tool in such a status that next person may use it without any problem.
- A reservation will be considered as cancelled, in case no work has started 30 minutes after the starting time.

3.5 Working hours

Working alone in the cleanroom is strictly prohibited. At least one colleague must be present. When announcing the intention to work odd hours, at least one co-working colleague should be stated. When the work load in the cleanroom is diminished to such an extent there being only two users present in the cleanroom, the user and colleague have a mutual responsibility for each other.

Approved users have access to the lab 24 hours a day, all year, with the exception of certain holidays.

Special processes, (involving highly toxic gases or high temperatures) may under no circumstances be used outside normal work hours (unless authorized lab personnel are present).

Other tool/systems may be used outside normal work hours only if at least one additional approved user, a ”lab buddy”, is present. This approved lab buddy must be present in the lab to be able to assist you in the event of an accident. The lab buddies must be in close contact with each other (NOT by mobile telephone!) to make this system work efficiently. The lab buddy should be nearby especially if you are about to use chemicals in the wet benches outside normal work hours. Additional procedures and restrictions may be applied to special tools. You will be informed about this when you get your tool license training. The lab buddy person must be an approved user.

. Only standard processes and well known written recipes are allowed to be used. Lab experience is demanded from those who want to work odd hours.

Be aware that special rules may apply at individual cleanroom laboratories!

3.6 Costs and charges

The running costs for a cleanroom facility are significant and include, e.g.,

- **Rent:** for the lab space and adjacent areas such as the sub fab, fan area, and storage rooms for gases and chemicals.
- **Personnel:** for maintaining the facility, tools and administration.
- **Consumables:** such as gases, chemicals, spare parts, utensils and cleanroom garment.
- **Power:** for running the tools, but also including a major part for fans and climate (heating, cooling, humidity control).
- **Depreciations:** for investments in tools and the facility.

Most of the costs are independent of the total usage of the lab, which makes it beneficial to increase the usage in order to distribute the fixed costs on a larger amount of lab users.

All Myfab laboratories apply a common user fee model, as described below:

- The fee is calculated per individual user and calendar month.
- A fix access fee should cover administration, consumables and usage of simple (non bookable) equipment.
- Usage of more advanced tools is charged by the hour, at a rate which is differentiated into five levels. Either booked or logged time may be used, and this choice may vary between the nodes.

- For each month and individual, a breakpoint (cost level) may be defined above which further usage is subject to a discount. The application of this option may vary between the nodes.
- All fees and other parameters differ between academic and industrial users. An intermediate level, primarily intended for research institutes, may under certain conditions be offered to small start-up companies (micro enterprise).

In addition to this model, each node may offer additional options for internal users.

The models are aiming to – in a fair way – distribute the total running costs of the facility between users and user groups, and to reflect the actual costs for each user's way to use the facility. But the models are also set to make the charges easy to handle and to estimate.

The fees are invoiced per user group and the basis for the lab fees could be the number of users, the total time spent in the cleanroom, the number of booked or logged tool hours or the total project volume. Costs for "standard" expendables (chemicals, gases, wipers, garment etc.) supplied by the process lab are included in the fee. However, special items, such as special wafers, expensive materials or non-standard chemicals will be charged based on the consumption.

It is of utmost importance that all lab usage is logged and presented in a proper way, to obtain a fair distribution of the costs.

3.7 Visitors

Visitors can be taken to the visitor's corridor around the cleanroom, which offers a view of the cleanroom area. Lab users may give this type of tour for small groups without prior approval by the management of the Laboratory. However, as a guide, you are always responsible for the safety and behavior of your visiting group. Visitors may only enter the cleanroom as an exception, and then only after prior approval by the Laboratory manager. Prior to the visit, these guests must be given a short introduction to cleanroom behavior. All photographing requires approval by the lab management.

4 Work environment and Safety

4.1 Risk assessment in the work environment

Risk, in general terms, relates to an event, the probability of the event occurring and the negative impact of the event. Larger probability of the event occurring and greater negative consequences contributes to the overall risk. One could say that risk is the product of the probability for the event taking place and the negative outcome of the event. This is the definition of risk most often used; in poker, economy, nuclear industry, rescue services, etc.

Work environment risks in the Myfab cleanrooms are unintentional and undesirable events with negative impact on health where the events are related to procedures, tools, chemicals, processes, etc., that are performed or present in the cleanrooms.

Negative outcome of an event in an economical context is easy to measure; it is the net loss of money. Negative impact on health or environment is more complex to measure or place in order of severity. However, some distinctions could be made:

An injury can inflict more or less pain. An injury can affect life quality for a limited or longer period of time, or be permanent. The impact on life quality may be small or severe. The injury may or may not be reparable. An injury could be fatal.

Reparable injuries that inflict minor pain or discomfort, and hinder everyday life for a shorter period of time, must be viewed as a fairly mild consequence. Fatal accidents or irreparable injuries, that will severely reduce life quality permanently, are severe consequences.

Preventive actions must be taken to reduce either the probability of such an accident (change of procedure, modifications to equipment, etc.), or the consequences (use of protective gear, detection of harmful chemicals, etc.).

The above is best illustrated with an example. The wet bench, as described earlier, provides a good protection against airborne chemicals, but no protection against splashes. Most wet benches are operated with corrosive chemicals. Splashes can be produced from simple handling mistakes, such as dropping an item into a container. It is fair to assume that a statistically relevant portion of such accidents will produce splashes that reach the face of the operator. This is a serious risk, which is easily reduced by the use of proper face covering protective gear. Splashes may still reach the operator, but the damage it can induce is greatly reduced.

- **Processing where it is possible to foresee likely scenarios where a mistake or accident can result in severe consequences can never be tolerated.**
- **Splashes of a corrosive liquid onto the face can result in permanent injury to the eyesight.**
- **All incidents and accidents must be reported to the laboratory staff.**

4.2 Work environment risks

Specific risks are:

- Chemicals with dangerous properties
- Process gases
- Electrical hazard
- Fire hazard
- Laser radiation
- X-ray radiation
- Nanomaterials
- Harmful metals

4.2.1 Chemicals

Fundamental for the safe use of a certain chemical is of its properties. That information is attainable from experienced colleagues, laboratory staff, the person responsible for the tool where the chemical is in use and in particular from the **Material Safety Data Sheet (MSDS)** from the supplier.

If medical attention is necessary as a result of exposure to a chemical, the MSDS of that chemical should be presented to the physician. Only chemicals that are approved by the laboratory staff may be used in the cleanroom. If there is a need for a new chemical, that chemical should be presented to the laboratory staff responsible of chemicals, together with the supplier's MSDS and an account of how this chemical will be used in a safe manner. If the chemical has dangerous properties, and the responsible function at the laboratory concludes that the risks cannot be lowered by the use of proper tools, procedures and protective gear, processing involving the chemical may be denied. Similarly, Myfab does not accept the use of dangerous or environmentally unfriendly chemicals, if there are better alternatives.

Properties and their corresponding symbols of some of the chemicals used in the cleanrooms:

Flammable

Corrosive

Toxic

Harmful

Dangerous to the Environment

Oxidizing

The cleanroom is supplied with a set of standard chemicals. All non standard chemicals are personal, meaning that they are purchased and used by a user or a specific project.

All standard chemicals are of VLSI-quality unless only other grades are available.

Below follows an exposition of (wet) chemicals that are present in the Myfab cleanrooms.

4.2.1.1 Bases

Bases are corrosive and will damage human tissue. Especially the eyes are vulnerable to exposure, since bases are difficult to rinse off. Bases may only be used in dedicated wet benches and fume hoods. Common bases in the Myfab labs are (Potassium Hydroxide) KOH, (Sodium Hydroxide) NaOH, (Ammonium Hydroxide) NH_4OH, (Tetra methyl ammonium hydroxide) TMAH and photoresist developers (typically containing NaOH or TMAH).

4.2.1.2 Acids

Acids are corrosive and will damage human tissue. Especially the eyes are vulnerable to exposure. Acids may only be used in dedicated wet benches and fume hoods. A supply of typical etchants is provided as standard stock in the cleanroom. Acids can induce chemical burns to the skin if exposed, be toxic, cause rapid heating through exothermic reactions (and thermally burn the body) and even initiate explosions.

Examples include: Hydrofluoric acid (HF), Hydrochloric acid (HCl), Sulfuric acid (H2SO4), Nitric acid (HNO3), Ammonium Fluoride NH4F, Perchloric acid (HClO4) and Acetic acid (C2H4O2).

4.2.1.2.1 HF (Hydrofluoric Acid)

HF is highly toxic and corrosive. The toxicity is due to the fluoride ion content of HF. Any solution containing a source of free fluoride ions is also toxic. Chemicals such as HF, NH4F and the mixture of the two (BOE, BHF), may differ in concentration, vapour pressure and volatility, but the fundamental toxicity is the same.

Fluoride ions readily penetrate the skin, causing destruction of deep tissue layers. Symptoms of exposure to low concentrations can be delayed. Exposure to concentrated HF (50% by weight) cause immediate, severe, burning pain and a whitish discoloration of the skin. The fluoride ions have a high affinity for calcium and magnesium ions. Chemical reaction between them forms water insoluble calcium- and magnesium fluoride salts. Local tissue destruction (at the point of contact) results from free hydrogen ions which cause corrosive chemical burns, and free fluoride ions which cause deep tissue destruction from the reaction with calcium ions in the human cells.

HF acid is essentially a gas dissolved in water. The vapour pressure of HF is high at room temperature, and HF acid will produce toxic and corrosive fumes.

In the body, Ca and Mg ions mediate a variety of physiological processes, as muscle movement and body chemistry. Skin exposure to greater areas (more than 160 cm2) or inhalation of HF vapours, may lead to systemic toxicity. Systemic conditions include hypocalcemia (loss of calcium) and hyperkalemia (too much potassium). Since calcium and potassium regulate the heart rythm, an arrhythmia and cardiac arrest can result. Fatalities have been reported from concentrated HF burns to as little as 2.5% of the total body surface. That is the equivalent of a single hand.

Dilute HF must be treated with the same caution as concentrated HF. Symptoms to exposure can be delayed. Exposure to 5% HF (by weight) may not produce symptoms for up to 24 hours. Treatment will be delayed correspondingly for unnoticed exposure, increasing the risk of local tissue destruction and systemic toxicity.

Calcium gluconate gel (aka “HF antidote”) for treatment of HF burns is available in the cleanrooms. Consult the lab specific appendix for locations.

4.2.1.2.2 Piranha

Piranha (or 7-up) is the mixture between sulfuric acid and hydrogen peroxide, usually in a 3:1 ratio. The international nick name for this mixture is Piranha solution.

Piranha is used mainly to clean wafers from photoresist residues or other organic contaminants. When mixed, sulfuric acid and hydrogen peroxide reacts; the hydrogen peroxide will undergo decomposition, producing highly reactive oxygen radicals that will oxidize most carbon -containing species. The sulfuric acid and hydrogen peroxide are themselves oxidizing agents and the sulfuric acid will act as an excellent solvent for oxidized carbon species. The reaction between sulfuric acid and hydrogen peroxide is highly exothermic, and the temperature of the mixture will initially rise to at least 120 °C.

The Piranha solution combines chemical corrosive properties with high temperature, and is used in dedicated wet bench containers which provide none or little splash protection. The Piranha mixture must be prepared and used with caution, always using proper protective gear.

If hot Piranha reaches the face in an accident, the result will probably be instant, permanent damage to the eyesight and skin burns that will leave disfiguring scars.

4.2.1.3 Organic solvents

Isopropanol (isopropyl alcohol – IPA) and Acetone are the most commonly used organic solvents in any microelectronic cleanroom. Isopropanol is a general cleaning agent for both wafers and equipment. Acetone is used to remove resist, clean wafers and resist contaminated equipment, etc. The properties of these solvents, and the effect they may have on humans, are well known. Health related risks are fairly low when handling Isopropanol and Acetone.

However, they are both flammable liquids.

Other organic solvents are used within Myfab. Some are more or less toxic, cancerogenic or mutagenic. For some solvents the health affecting properties are not known or fully understood, which may also be true for other chemicals than organic solvents. Such chemicals should be treated as toxic. Always consult the MSDS before starting to use a new chemical. With very few exceptions (e.g. IPA), the use of organic solvents must be confined to ventilated workstations.

Not only Isopropanol and Acetone are flammable. For the sake of simplicity, all organic solvents should be considered flammable.

Some organic solvents are known to be cancerogens or toxins. They should be avoided if there are less toxic or cancerogenic alternatives to use. For example, if ethanol could be used rather than toxic methanol in a process, then it should. The cancerogen Benzene can sometimes be substituted with Toluene.

With the use of Isopropanol and Acetone follows a fire risk.

Figure 19 Chemical storage

4.2.1.4 Cryogens

Liquid nitrogen (LN_2), Liquid Argon, Liquid Helium and Solid CO_2 (dry ice) are examples of cryogens. Cryogenic chemicals present a safety hazard due to their extreme cold. Users should be familiar with this hazard and use appropriate cryogen gloves as well as designated personal protective equipment against the freezing effects. Under no circumstances should a user allow to contact LN_2 with their body. Severe injury can result from such contact.

All cryogens listed above can displace the oxygen in the air as they evaporate. Therefore you must only use nitrogen, liquid nitrogen, helium, liquid helium and carbon dioxide in well-ventilated rooms and after having performed an analysis of the amount of air that could be displaced by the cryogen proposed for use. Provided only a small fraction of the air will be displaced, the cryogen can be used safely. Keep the room especially well ventilated during use.

4.2.1.5 Photoresist and other organic chemicals

Special organic chemicals like photoresists, epoxy resins, adhesives, and so on, are also present in the cleanrooms. They most often do not have the same acute corrosive or toxic properties as acids. However, if they are handled in a faulty manner over time, this may lead to a long-term exposure to the skin or respiratory system with known or unknown consequences as a result.

Most photoresists are mixtures of solvents, novolac resins and photo-active compounds. The resulting mixture can be toxic, flammable and/or irritating. Use these chemicals only in approved ventilated areas, such as solvent hoods or photoresist spinners.

Fumes evolved during use of photoresists, polymers, etc., must not be inhaled. Dedicated workstations like spinners or bake ovens are fitted with exhaust ventilation; if it smells there is a technical problem with the equipment or the handling procedure.

Epoxy resins are known to induce sensibilisation from prolonged skin exposure. Sensibilisation is an allergy-like condition with low tolerance to expoxy, and possibly other chemicals and allergens.

4.2.1.6 Hydrogen peroxide

The only significant standard chemical that cannot be put in any of the above categories is hydrogen peroxide. This chemical is a strong oxidizer and may react violently when mixed with other chemicals. Using hydrogen peroxide in mixtures is therefore limited to well known recipes like 7-*up* (*Piranha solution*) or other standard mixtures.

4.2.2 Harmful metals

Some of the metals used in evaporation processes in the cleanroom are harmful and should be treated with high precaution.
Nickel (Ni) shows limited evidence of carcinogenic effects and may cause sensitization by skin contact.
Chrome (Cr) is very toxic in contact with skin and if swallowed. It is also harmful to inhale.
Read the MSDS prior to use!

Working rules:

- Always use protective gloves and visor/goggles (Cr); avoid direct contact to the skin.
- When working with the metal or mechanical cleaning of tool parts (risk for particle generation) take precautionary measures against dispersal and accumulation of metal particles. Work in a fume hood or use respirator (andningsskydd).
- Metal remains and/or contaminated tool parts to be replaced (boats, shields, etc.) should be treated as hazardous waste: wrapped in plastic bag and left to the destruction.
- Chrome: in case of contact with eyes, rinse immediately with plenty of water (for 15 minutes) and seek medical advice.
- Chrome: in case of accident, if you feel unwell or experience other effects, seek medical advice immediately.

4.2.3 Process gases

In the cleanroom there are several dangerous gases in use. Toxic, corrosive and flammable gases are used in various applications. There are two main risks with hazardous process gases:

- Leakage that may expose users to a toxic or corrosive gas.
- Fire induced by leakage of technical fault in tools using flammable gases.

Cabinets, distribution boxes, and PoU boxes that contain toxic, flammable, or corrosive gases, are connected to exhaust ventilation. In addition, one or more gas detectors are installed in each unit. Detected leaks will be displayed at a monitor, and, if necessary trigger evacuations alarms and for some tools also interlock the gas distribution (target gas and concentration dependent).

Typically the evacuation alarm will start at Threshold Limit Value - Time Weighted Average (TLV-TWA). The TLV for chemical substances is defined as a concentration in air, typically for inhalation or skin exposure. Its units are in parts per million parts of air (ppm) for gases. Three types of TLVs for chemical substances are defined:

1. Threshold Limit Value - Time Weighted Average (TLV-TWA): average exposure on the basis of a 8h/day, 40h/week work schedule
2. Threshold Limit Value - Short Term Exposure Limit (TLV-STEL): spot exposure for a duration of 15 minutes, that cannot be repeated more than 4 times per day
3. Threshold Limit Value - Ceiling (TLV-C): absolute exposure limit that should not be exceeded at any time

4.2.4 Electrical hazard

The cleanroom is fitted with a vast collection of electrical tools. The power consumption in the cleanroom per square meter is significant. The result of an accident involving electric chock may range from discomfort to instant death. Current strength and current path through the body decides the outcome of an electrical chock. An electric current that passes from hand to hand or hand to foot, is most likely fatal if it is in the range 50-500 mA, due to effects on the nervous and muscular system (heart failure). Higher currents normally do not kill instantly, but will burn interior and exterior parts of the body, giving permanent or eventually fatal injuries (failure of internal organs, burns that are complicated by infections, etc.). Interior burns from currents in the range 50-500 mA may also give long term problems locally or to the kidneys, if the hemoglobin coagulates in blood vessels from the heat induced by the current.

It is not allowed for users to perform trouble shooting or repairs on tools.

4.2.5 Fire hazard

The combination of chemical usage, flammable process gases, high area density of electrical tools and tools working at elevated temperatures, increases the probability of a fire incident. The outcome of a fire may be severe consequences to the cleanroom and its users as well as the environment surrounding the cleanroom, due to the presence of toxic gases and chemicals.

Fire is a very serious condition, and fire prevention must always be a priority.

4.2.6 Laser radiation

Some tools uses laser radiation. A laser is a device that emits light (electromagnetic radiation) through a process called *stimulated emission*. The term "laser" is an acronym for *Light Amplification by Stimulated Emission of Radiation*. In some laboratories lasers are used for characterization and other experiments. There are lasers of varying wavelength and intensity. Laser radiation damages the eyes instantly if they are exposed and the resulting intensity of the incoming radiation is great enough. This means that a direct reflection of a low intensity beam, as well as diffuse reflection from a high power laser, may damage the eyes. No indication of the presence of radiation can generally be said to exist. That is, the damage is most likely instant and the radiation is not necessary in the visible spectra. The damage done by laser radiation to the eyes is primarily by instant, local heating of tissue, resulting in blind spots, reduced eye sight or blindness. In addition to the risks to the eyes, short- and long-term effects like burns or cancer may be the result from (prolonged) exposure to the skin.

Lasers are usually labeled with a safety class number, which identifies how dangerous the laser is:

- Class I/1 is inherently safe, usually because the light is contained in an enclosure, for example in cd players.
- Class II/2 is safe during normal use; the blink reflex of the eye will prevent damage. Usually up to 1 mW power, for example laser pointers.
- Class IIIa/3R lasers are usually up to 5 mW and involve a small risk of eye damage within the time of the blink reflex. Staring into such a beam for several seconds is likely to cause (minor) eye damage.
- Class IIIb/3B can cause immediate severe eye damage upon exposure. Usually lasers up to 500 mW, such as those in cd and dvd burners.
- Class IV/4 lasers can burn skin, and in some cases, even scattered light can cause eye and/or skin damage. Many industrial and scientific lasers are in this class.

The indicated powers are for visible-light, continuous-wave lasers. For pulsed lasers and invisible wavelengths, other power limits apply. People working with class 3B and class 4 lasers can protect their eyes with safety goggles which are designed to absorb light of a particular wavelength. **Never look directly into a laser beam and bear in mind that the light may be reflected!**

4.2.7 X-ray radiation

X-radiation (composed of X-rays) is a form of electromagnetic radiation. X-rays have a wavelength in the range of 10 to 0.001 nanometers, corresponding to frequencies in the range 30 petahertz to 30 exahertz (30×10^{15} Hz to 30×10^{18} Hz) and energies in the range 120 eV to 120 keV. They are shorter in wavelength than UV rays. In many languages, X-radiation is called Röntgen radiation after one of its first investigators, Wilhelm Conrad Röntgen.

Such radiation is emitted from diffractometer tools and ion implanters. This is taken into consideration by the design engineers and the tool is normally shielded. However, alterations of the tool or an unsafe operation may reduce the effiecency of the design considerations, thus exposing personnel to X-ray radiation. The physical consequences to exposure can result in mutagenic or cancerogenic effects.

4.2.8 Nanomaterials

Nanomaterials are applications with morphological features smaller than a one tenth of a micrometer in at least one dimension. Despite the fact that there is no consensus upon the minimum or maximum size of nanomaterials, with some authors restricting their size to as low as 1 to ~30 nm, a logical definition would situate the nanoscale between microscale (0.1 micrometer) and atomic/molecular scale (about 0.2 nanometers).

The hazards associated with handling of novel nanomaterials are still under debate, but first of all those new materials are not yet proven to be non-hazardous. We require that our users keep updated on information about the potential risks with their material, and using the appropriate precautions during handling.
A good recommendation is to start reading the following 2 links;
(http://membership.acs.org/c/ccs/nano.htm) and the European project Nanosafe
(http://www.nanosafe.org/)

4.3 Routines for handling of chemicals in the cleanroom

The following routines apply to all handling of chemicals in the cleanrooms:

- Put chemical protective gloves over the Nitrile gloves before you start working with chemicals at the process benches.
- Put on a face protective visor when required.
- Inspect your gloves carefully. If the gloves are discolored or damaged, they should be disposed of and replaced immediately. Rinse the gloves carefully before placing them into the trash bins. New gloves are acquired from the person responsible for Service and Maintenance.
- Chemicals may only be handled at a process bench.
- Apply the Acid-Into-Water rule. AAA- always add acid
- Never mix chemicals without prior knowledge of the consequences.
- Some containers/beakers are dedicated for certain chemicals, and may not be used for anything else.
- Hydrofluoric acid (HF) and Potassium Hydroxide (KOH) solutions may only be used in plastic containers.
- Open containers containing Ammonia (NH_3) and Hydrochloric acid (HCl) may not be placed next to each other, as the chemical reaction between the vapours will generate solid particles in the cleanroom.
- Chemicals in containers that are not clearly labeled should be disposed of immediately. Mark the container ”unknown content” and call the lab personnel.
- Some chemicals are being re-used. Pour this back into the bottle and carefully rinse the container with pure water.
- After the work in the process bench has been completed, the chemical protection gloves should be rinsed and put back to their designated place, without touching any surface besides the process bench.
- Pay special attention while you are working with Hydrofluoric acid (HF). This acid may cause severe burns into the bone marrow, and the symptoms may sometimes not be noticed until 24 hours after the exposure. Any exposed skin should be covered with ”HF Antidote Gel”. Spread the gel and contact a physician as soon as possible. The paste is available near the process benches that contain HF. Please note that HF is a component of BOE (Buffered Oxide Etch).
- Ensure that flammable chemicals (e.g. acetone or propanol) are not used near hot surfaces. Even small amounts may cause fire incidents.
- You may not introduce previously unknown chemicals without prior approval from the lab manager. Purchase of chemicals should be done through the lab staff.
- Do not disturb persons working with chemicals.
- The user is responsible for cleanup of minor chemical spills. Please contact the lab group if a major spill has occurred.
- Do not dispose of used chemicals if you are not sure how to do this. Store in closed bottles/containers until further notice. This applies especially to concentrated, unmixed chemicals. Contact the lab personnel for advice.

4.4 Chemical cupboards

Chemicals and chemical wastes have to be store in ventilated cupboards. Only compatible chemicals are allowed to be stored in the same cupboard. There are mainly three different types of cupboard that are assigned for storage of chemicals of three different groups:

a) Acid cupboards: Chemicals that are inorganic acids, base, oxidizing or water based chemicals, as well as non-toxic inorganic salts should be stored in such cupboards. These cupboards are connected to the acid exhaust system.
b) Solvent cupboards. These cupboards are assigned for storage of only organic solvents. Solvent cupboard are connected to the solvent exhaust system
c) Toxic chemical cupboards: Are connected to toxin exhaust system and used for storage of toxic chemicals. Note that:
   - The toxin cupboards must always kept locked.
   - HF and buffered HF should be stored in the acid cupboards but not toxin cupboards.

If you want to store a mixture of different chemicals contact the staff in charge for further assistance. Some cleanrooms have dedicated cupboards for bases and photoresists (see local conditions).

4.5 Ventilated work places

Wet benches and fume hoods represent two different technical solutions to the problem of handling chemicals in a safe manner.

Generally speaking, a solution to this problem should contain:

- A way to separate the user from any harmful airborne pollutants.
- A surface to work on.
- A way of disposing of the chemicals after usage.
- A choice of materials that is compatible with the intended chemicals.

4.5.1 Fume hoods

Fume hoods are designed to protect people from fumes and chemical splashes. The fume hood is an exhaust ventilated work space with a see-through height adjustable sash. The exhaust ventilation will constantly draw air into the fume hood. If the air velocity in the hood opening is at least 0.5 m/s, airborne chemicals will not escape into the room. The sash gives an excellent protection against splashes. Typically fume hoods require airflows in the range 500-800 m^3/h, depending on hood geometry and design principle.

A traditional fume hood operates with fixed airflow. This means there is a damper on the exhaust ventilation duct behind the fume hood. The damper is adjusted to a fixed position, so that the air velocity is at least 0.5 m/s when the sash is raised to a certain standard height. If the sash is raised further, the air velocity will drop. If the sash is lowered, the velocity will increase.

There are also fume hoods with variable airflow. The damper is in this case actuated by a step motor which is controlled by a pressure gauge. If the sash is opened above the standard height, the damper will open, thus increasing the airflow and maintaining sufficient velocity through the hood opening.

Regardless of design, all fume hoods must be fitted with ventilation guards that monitor the air velocity (directly, or indirectly by measuring the pressure in the hood). If the velocity decreases to an unsafe level, an audio alarm signal is normally given.

Fume hoods are connected to one of two available exhaust systems, acid exhausts in PVC and solvent exhausts in sheet metal. (Check local conditions). When working with large volumes of chemicals, fuming chemicals or at high temperatures it is necessary to use a hood with the correct extract system. For small volumes at room temperature it is not essential to use the fume hood.

There are typically two or three independent drainage systems in fume hoods:

- The acid drainage is used for acids and bases. The effluent is drained to a neutralizing tank on the floor below the cleanroom.
- The solvent drainage is used for organic solvents (possibly with exception for halogenated solvents, consult with laboratory staff). The effluent is drained to a waste storage tank.
- Drainage directly to the public sewer (optional, only for water).

Keep in mind the following fume hood working principles:

- Respect the ventilation guard. If the alarm is on, the fume hood provides an insufficient protection against airborne chemicals. Low exhaust capacity in the fume hood may be locally induced (sash is opened to high) or due to a problem with overall capacity (failed exhaust fan).
- Use the fume hood with the sash opened to the minimum height your work requires.
- Always use the sash as splash protection. That is, position the sash so that you work looking through it.
- Do not place beakers or containers with chemicals closer than 15 cm to the front edge of the fume hood. This simple rule together with proper use of the sash ensures good protection.
- The cross sectional geometry of large containers or equipments placed in the fume hood can result in insufficient airflow in front of the object. Air will escape above and on the sides of the object, but fumes may diffuse out from the objects front. If the object is placed on 5 cm spacers, air will flow also beneath the object, improving the protection.
- **Mind the fire hazard!** Flammable chemicals must be handled with caution. Consult the MSDS for properties of the chemicals you are handling. Organic solvents are always flammable. Do not leave beakers or containers with organic solvents unattended together with possible sources of ignition like electrical equipment, especially not hot plates. A fire in a fume hood will initially not be detected by the smoke detectors, since the smoke effectively will be removed by the exhaust. If the fume hood is connected to a PVC duct, the fire can propagate through the exhaust ducts.
- **Mind the safety of other users!** Clean the work area after using the fume hood. Never leave chemicals, beakers, warm hot plates etc unattended in the fume hoods. If it is necessary to leave before the process is complete, a note indicating name, telephone number, chemical contents and date must be clearly visible.

4.5.2 Wet benches

The wet bench is an exhaust ventilated work table. The height and depth of the wet bench are suitable for working in an upright position. The top surface is perforated and fitted with recessed chemical baths suitable for cassette handling of wafers. Air flows through the perforation. The baths are covered by lids that open in a flip-up fashion. When a lid is open, air flows through an open section surrounding the container. Some benches have a ceiling attached screen above them, and HEPA-filters are installed in the ceiling area onto which the bench is projected. The screen and the filters will provide clean air to the bench surface, and if the air supply is in balance with the bench exhaust, vapours are effectively removed. The wet bench provides a much cleaner handling of wafers than the fume hood. The latter draws air from the cleanroom ambient in an uncontrolled manner; the air is not drawn directly from the HEPA-filters, and will pass the operator, picking up particles.

Wet benches provide good protection against harmful vapours from acids (or other liquids) in the containers, but are less effective for chemicals handled on top of the work surface. The maximum safe working height is 200mm. (Local regulations may exclude handling of chemicals on the top surface). Above the stipulated maximum working height, vapours from the container can escape into the room. A safe working distance from the bench edge is 15 cm or more.

Work is performed with chemicals in the line of sight, without any see-through screen in between. If an item is dropped into a container, splashes will be the result. Since all wafers are handled by cassettes or wafer holders, there is certainly a risk potential in the bench construction and operation. Preferably an apron should also be used (consult local regulations).

If the perforation in the top surface is covered by papers, beakers and other items, the airflow through the bench will be reduced. The air supplied to the bench from the filter ceiling is constant, and will in this situation exceed the exhaust flow. The excess air will “roll” over the front edge of the bench, possibly bringing with it vapours from the bench chemicals.

Common functions in wet benches are drain valves, heated chemical baths, ultrasonic baths, etc. These functions are operated from a manouvering panel on the bench front. The protective gloves are used to protect your hands. Assume that they will be contaminated with corrosive chemicals when moving cassettes or holders over the baths. Such contamination should not be tansfered to the manouvering panel. Rinse of the gloves with a DIW-gun, remove them and operate the panel with your cleanroom gloves.

- **Observe that the wet bench provides no protection against splashes at all.**
- **Face covering shield and protective gloves must be worn when operating a wet bench.**
- **Cleanroom gloves must not be considered as chemically protective gloves.**
- **The top surface should be kept free from unnecessary items.**
- **Do not touch the manouvering panel with protective gloves on.**

4.6 Safety policy

The Myfab laboratory environment is challenging and interdisciplinary from a technical point of view. Many tools and processes use hazardous chemicals or gases, operates at high temperatures or voltage, etc. The very physical or chemical properties or phenomena that are beneficial in a process can also be a threat to the health and wellbeing of people and equipment. Myfab recognize that expertise in specific processing must be followed by necessary understanding of related work environment risks. It is the expertise of the people working in the Myfab laboratories that is the foundation for a safe work environment.

The Swedish work environment authority regulates laboratory work, and other types of work relevant in the Myfab laboratories. The Myfab laboratories comply with regulations, and keep track of new or changed regulations.

The Myfab labs have agreed to comply with the following simple but effective statements:

- One single mistake or error should not result in a catastrophe.
- Zero concentration of toxic substance in the air where people work.
- Below threshold limit value of highly toxic substance in exhaust ducts.
- Tools handling toxic substance at elevated temperatures together with explosives or flammable gases must be supervised on-site.
- New processes, which are potentially dangerous, should be approved by the safety officer.
- Repair or modifications of tools handling toxic, explosive or flammable substances, x-ray radiation or laser (class 3B or 4) radiation must be performed by authorized personnel.
- Potentially dangerous or hazardous work must be executed during office hours.

If an incident (or accident) occurs, despite efforts of preventive nature, incident must be reported to laboratory staff for investigations into possible modifications of tools, procedures or rules, in order to prevent that the incident is repeated in the future. We also encourage all our users to inform the lab staff whenever any potential dangerous behaviour or situation is observed, in order to also prevent possible accidents.

4.7 Alarms

Alarm systems in the Myfab labs may be divided into the following categories:

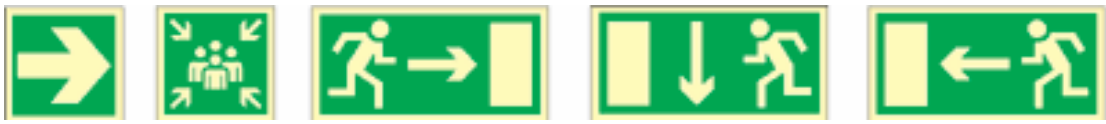
- Fire alarm: Smoke detectors, manual activation, possibly heat detection, sprinkler system.
- Systems for detection of specific hazardous gases.
- Operational alarms. That is, failure or deviations within the cleanroom infrastructure.

These alarm systems will trigger an internal alarm notification system. Typically the highest alarm level is total evacuation of the cleanroom, and is indicated visually by red light signals and audible signals from sirens or horns. Fire alarm and certain concentration levels of hazardous gases will trigger the total evacuation alarm. Operational alarms are indicated visually by blue light signals (and possibly by an audio signal - check local conditions), and does not necessitate evacuation.

The total evacuation alarm will not only indicate the alarm for the cleanroom users, but also induce necessary actions in the infrastructure, with respect to ventilation, house gas distribution, tool shut down, etc.

The alarm system and –scheme for each Myfab lab are described in the lab specific appendix.

4.7.1 Evacuation of the cleanroom



An evacuation alarm must result in an immediate response from the cleanroom user:

- **Without hesitation, go to the nearest emergency exit and leave the cleanroom.** Emergency exits are marked with green and white signs according to international standards. All clean zones have emergency exits in the very room where work is performed. At all locations in the cleanroom there are at least two alternative ways out.
- **Go to the reassembly point and await further instructions.** Do not leave the reassembly point unless laboratory staff authorizes this action.
- **When evacuating do not waste time removing your cleanroom garment, leave it on. Do not delay evacuation by trying to end work that otherwise might be spoiled.**
- **During evacuation be sure that your colleagues follow your example.** Help them if necessary and possible. Account if possible for the whereabouts of presumed missing colleagues.

Consult the lab specific appendix for details on reassembly point and what to do after an evacuation.

5 Safety gear and other technical aids

5.1 First aid

First aid boards with simpler first aid gear, band aids and such, are posted on several places (not in the cleanroom though). Familiarize yourself with the location and contents of the first aid kit.

5.2 Protective gear

For all applications in the cleanroom approved by Myfab, where protective gear is assessed necessary, such gear is normally available and must be used. If for some reason it is not available, the application may not be used. Protective gear can be glasses or face covering shades protecting the eyes against splash from acids or other harmful chemicals, protective gloves, gasmasks, and so on. The need for protective gear for each relevant application must be investigated before processing. This is done by reading the written instructions of that application, and/or by a verbal account from the instructor of that application. However it should be stated here that when working with wet chemicals, or being present in the close vicinity of such work, protective gloves and e protection must be worn at all times. Preferably also a protective apron should be worn. As eye protection, the fully face covering screen or shield is to prefer rather than protective glasses.

5.3 Fire extinguishers

There are fire-extinguishers mounted on several locations in the cleanroom. The locations are marked with an additional sign (see figure above). The extinguishers are of carbon dioxide type due to the nondestructive properties of that fire extinguishing media. A drawback with carbon dioxide is the need to approach the fire fairly up close, and the efficiency is poor compared to powder or foam. Cleanroom users are normally not expected to use fire-extinguishers, but different rules exist at the different sites.

5.4 Eye showers

The only way to remove harmful chemicals from the eyes and possibly save (parts of) the eyesight, is to rinse the eyes in an eye shower. The success of this action depends on two things. How soon after the exposure rinsing commences, and how thoroughly this is done. Rinsing should be continued for at least 10 minutes. Injuries to the eyes should always be inspected by a medical specialist. It is important that rinsing is continued during transportation to hospital, using a handheld bottle. During rinsing it is imperative to open the eye lids as much as possible, directing the water flow in to, and around, the whole eye.

This is awkward to do, even so with eyes that have not been exposed to chemicals. An injured person might therefore refuse to open the eyes. Instead keeping them closed thereby making the situation worse. If a person needs assistance in such an accident:

Guide him or her to the eye shower, remove any contaminated clothing that might hinder the rinsing. Start rinsing. Be firm but calm. If necessary convince, persuade or even force the person to open the eyes (using common sense, that is). If or when your colleague is able to continue the rinsing by her/his own, assist by removing contaminated clothes, rinse other parts of the body that have been exposed, etc.

When handling wet chemicals, one should always be aware of the location of the nearest eye shower. If splashes reach the eyes, it is for most acids, and alkaline chemicals in particular only a matter of seconds before the eyes get permanently damaged.

Eye showers are mounted in the close vicinity to most places where wet chemicals are used and handled. Installed together with each eye shower is a flexible hose with a shower head, which can be used to rinse of chemicals from other parts of the body than the face.

The proper way to deal with chemicals soaked into the clothing is to first rinse the parts of the body exposed without removing the clothing. Rinse thoroughly until the chemical is removed or the concentration diminished. For chemicals where applicable, test with pH-indicator. Then remove clothing and continue rinsing.

5.5 Emergency showers

Wall mounted showers for putting out fire in clothing, and possibly rinse of chemicals. If the area exposed with chemicals is local, then the hand held shower heads at the eye showers are more efficient. Emergency showers are mounted in the cleanroom corridor, and in most clean zones.

5.6 Antidote gel

The antidote gel is used to treat burns on the skin from hydrofluoric acid. It must always be available and within reach whenever HF is used. If the skin is exposed to hydrofluoric acid, rinse with plenty of water for 4-5 minutes. Check with pH-indicator that no acid is left on the skin. Apply the antidote gel all around and over the exposure in lavish amounts immediately. Repeat treatment every 10 minutes during the first hour.

In addition, anyone exposed to HF should go to an appropriate medical care facility for evaluation and treatment as quickly as safely possible.

Calcium gluconate provides extra calcium ions, which can scavenge free fluorine ions (to form CaF_2) before they penetrate your body and cause damage.

6 Appendix 1 In Case of an Emergency

112 is the special emergency call number which you can call with a fixed or mobile phone wherever you are in Sweden. Your call will be answered by an operator at one of the SOS Alarm centers which will dispatch the help needed.

When your 112 call is answered, the SOS Alarm operator will ask you the following questions:

- **What has happened?**
- **Where did it happen?**

Stay as calm as possible and try to describe clearly what has happened, where it happened, who needs help and why? Is there a fire, is anybody in danger due to the fire, or is somebody for instance in need of police protection? In the event of an accident, the operator needs to know if anybody is injured and, if this is the case, how many injured persons are there and in what way are they injured?

Describe clearly the place to which help needs to be sent and tell the operator your **name, address and telephone number.**

The SOS Alarm operator must have this information in order to determine what help is needed and to dispatch as quickly as possible the correct emergency service to provide the necessary assistance. The SOS Alarm operator may also need some more information while help is on the way. So stay on the phone or where you are for the time being.

112 is the public special emergency call number in Sweden for getting help from all the emergency services and the police. The SOS Alarm centers are accessible 24 hours every day and co-ordinate the dispatching of the emergency services. But you should only call 112 if you are in an emergency situation and immediate help is required. Your call may otherwise delay necessary vital help to people involved in accidents or other distress situations.

If your call is not urgent, then call the service numbers which you will find on the inside of the cover page of the local telephone directory.

At SOS Alarm centers, there are both male and female operators answering the emergency calls. Normally, the conversation must be in Swedish or English to enable the SOS Alarm operator to understand the call and dispatch quickly the emergency service needed. If time allows, SOS Alarm will when necessary involve an interpreter, but this may delay the call.

7 Appendix 2 Ångström Microstructure Laboratory Manual

8 Appendix 3 Electrum Laboratory Manual

9 Appendix 3 MC2 Nanofabrication Laboratory Manual