Myfab User Manual

Myfab - The Swedish Research Infrastructure for Micro- and Nanofabrication, 2017

Publisher: MYFAB

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Print: ARKITEKTKOPIA AB, 2017

Paper: Multiart Silk 300g (cover), Multiart Silk 130g (inlay)

Copies: 2000 ex.

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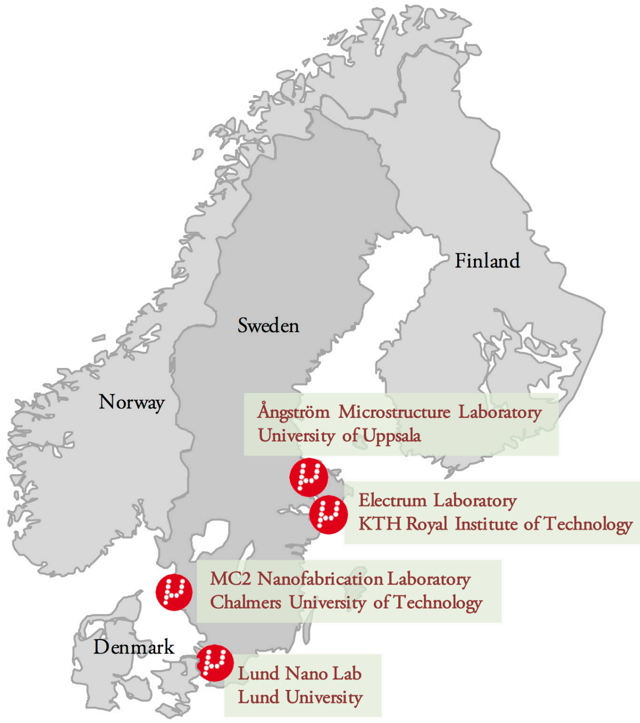
MYFAB WEBPAGE
http://myfab.se/



Myfab is the Swedish research infrastructure for micro/nanofabrication and characterisation. Its distributed infrastructure offers an wide platform for both academic and commercial interests in Sweden, Europe and around the world. You will have access to the best equipment available in Sweden, affording your research and technical development the possibilities they deserve.

The Myfab network includes:

- Myfab Göteborg: MC2 Nanofabrication Laboratory, at Chalmers University of Technology
- Myfab Lund: Lund Nano Lab, at Lund University.
- Myfab Stockholm: Electrum Laboratory, at KTH Royal Institute of Technology
- Myfab Uppsala: Ångström Microstructure Laboratory, at Uppsala University

Myfab is supported by the Swedish Research Council and by the four Myfab universities. Chalmers is host for Myfab. Each Myfab laboratory shall represent the whole infrastructure and provide guidance to the tools and expertise of all laboratories. All tools and related information is made available through the web-based Myfab LIMS system.

The main tasks of Myfab are:

- to provide the prequisite for world-leading research.
- to provide user-fee based open access to the infrastructure to users from academy, institute or industry.
- to provide adequate user training and user support,
- through Myfab's expert staff provide process advice, support and service.
- to identify and plan necessary investments, in particular in case of expensive investments and/or resource-intensive equipment national coordination is important.
- to provide seamless access to the whole distributed infrastructure on equal conditions.
- to bring funding and its application to a strategic level, beneficial to Swedish research.

As a user of one or more Myfab laboratories, you will be responsible for the safety, working conditions and success of others. This responsibility starts with this document (including relevant appendices), and you must be familiar and compliant with its contents at all times.

TABLE OF CONTENT

INTRODUCTION

The Myfab laboratories offer 5,400 m2 of cleanroom area and over 700 tools for the fabrication and analysis of structures with dimensions in the micro/nanometer range. This environment requires that all users have sufficient knowledge on how to behave and act in our cleanrooms.

This manual may be considered a general instruction manual on the basic usage and safety aspects common to all the cleanroom laboratories in Myfab. It is not possible to give a complete framework for all possible situations, but with this manual we try to address and describe the most important aspects. The manual is equally applicable to all laboratory employees and users. It governs the safety as well as the rules which must be followed for admittance and usage of the cleanrooms and tools.

This manual primarily covers safety and working conditions, including potential dangers. However, it also deals with important information on using the cleanroom. The first chapter describes cleanroom basics (their technical design and maintenance) while Chapter 2 informs the new user about administrative guidelines for starting up work quickly and effectively. Users will interact regularly with the Myfab LIMS website, the most important features of which are described in Chapter 3. To maintain the cleanroom quality specifications, all users must know and at all-time follow the common rules of cleanroom practice, described in Chapter 4. As safety is of utmost concern, Chapter 5 covers the safety hazards in our cleanrooms and Chapter 6 directly address the importance of working with chemical safety, to prevent accidents. There is also essential information for the user to help minimise adverse effects in the event of an accident (Chapter 7).

In addition to the general part of the manual, the four Myfab laboratories have their own site-specific safety rules and instructions in the appendices. A user who have participated in the introduction course on one site can obtain access to another site by adding up with those local rules and information as described in their appendix.

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

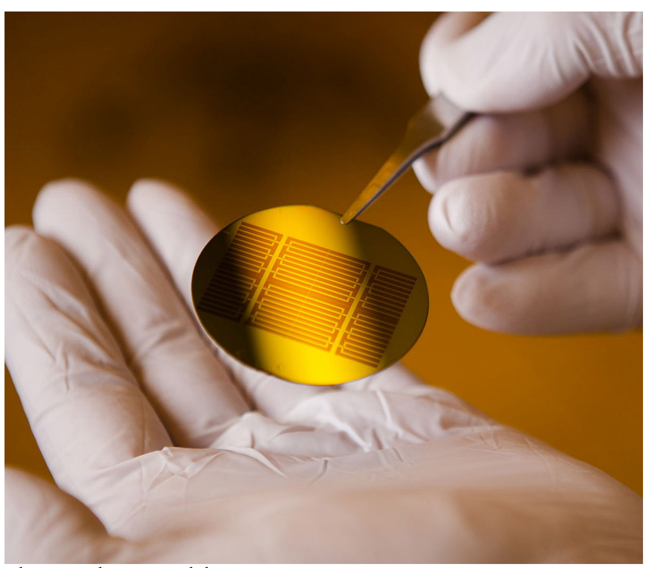


Photo: Nils Bergendal

myfab

1 CLEANROOM BASICS

1.1 Why do we need Cleanrooms?

Fabricating structures and devices with critical dimensions in the micrometer (10^{-6} m) to nanometer (10^{-9} m) range sets the bar very high for the fabrication environment. Thus, "contaminants" (such as particles or vibrations) harmful to certain process steps or the performance of end products, must be eliminated or significantly reduced. Important climate parameters (temperature, humidity, pressure) must be controlled to fine tolerances, if stable and reproducible process conditions are to be maintained.

Please note that the cleanroom, as described in this text, is intended for semiconductor processing and micro/nanofabrication. The considerations and technical solutions described here may not be the same as those for other scientific or commercial fields; ones where, say, sterility and microbe control may be primary concerns.

1.2 Cleanroom Environment

1.2.1 Particle Control

Small structures fabricated in the fields of microelectronics, photonics or microelectromechanical systems (MEMS), are all sensitive to submicron (and larger) particles. Particles adhering to wafers during specific process steps may reduce yield, affect device performance, or cause other kinds of damage. Any particle with a size comparable to, or larger than, the critical dimension of the device or structure is potentially bad for the yield. Figure 1 shows different types of particle contamination that can be generated by cleanroom users.

Figure 1: Sources of particles from cleanroom users.

Cleanrooms are designed and operated so that introduction, generation, and retention of particles is minimised. The addition of particles to a cleanroom environment is limited mainly by filtering intake air. Ventilation control and air filtering ultimately determine the lowest achievable particle concentrations in a cleanroom.

Particles are also introduced by people entering the cleanroom and the items they bring in. This effect can be reduced if users wear proper cleanroom garments (such as coveralls, hoods, masks, gloves and booties), as well as by entering through air locks and proper cleaning of all items introduced from outside. Humans can generate over 100,000 particles per minute at rest and over 10,000,000 particles per minute when walking quickly, see Table 1.

Activity	Particle generation
Sitting or standing still	100,000
Sitting, with arm, leg or head movements	1,000,000
Standing up	2,500,000
Walking quickly	10,000,000

Table 1: Particle generation (> 0.5 µm/minute) by cleanroom users; the main source of particles.

The garments act as particle filters between the lab user and the cleanroom, trapping and holding the particles emitted by the human body. A correct outfit will reduce the spreading of particles, but each individual is also responsible for further reduction of particle generation and spreading by practicing a correct behavior. Figure 2 shows how particle levels near the entrance of a cleanroom correlates with working hours and human activities.

Particle generation inside the cleanroom is suppressed by observing correct working procedures and eliminating particle-generating materials. Common materials such as paper, pencils, and fabrics made from natural fibres are normally excluded and replaced by cleanroom-compatible equivalents. Retention of particles is suppressed by diluting the cleanroom air through recirculation and filtration, as well as frequent cleaning.

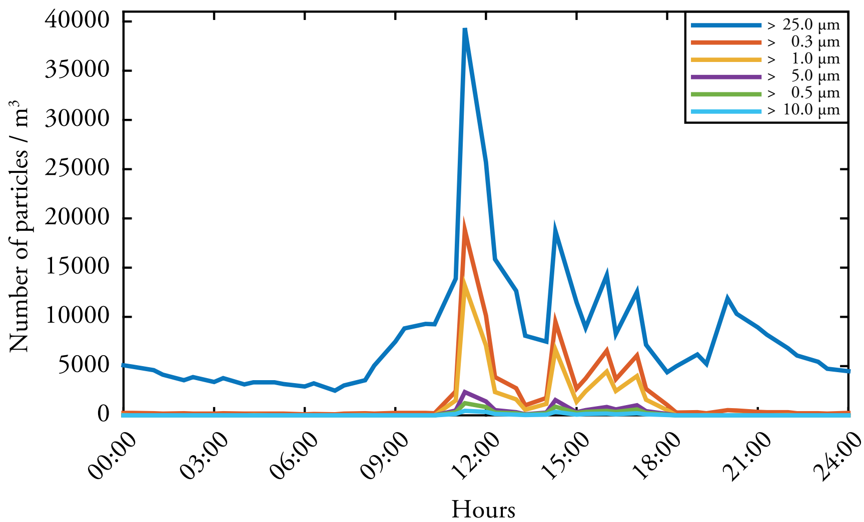


Figure 2: Particle-level diagram at different times of the day.

1.2.2 Cleanroom Classifications

Cleanrooms are classified according to the number and size of particles permitted per volume of air. The ISO standard is based on the decimal logarithm of the particle density, see Table 2. The older US FED 209 standard, which referred to the maximum number of particles in a cubic foot of air, is still in use. Depending on the specific activities and requirements, the classification varies within and between the Myfab cleanrooms.

Simplified ISO 14644-1 airborne particle cleanliness classes (maximum level of particles / m^3)								
ISO class	1	2	3	4	5	6	7	8
Corresponding Fed Std	-	-	1	10	100	1,000	10,000	100,000
No. of particles ≥0.5 µm	-	4	35	352	3,520	35,200	352,000	3,520,000
No. of particles ≥0.1 µm	10	100	1,000	10,000	100,000	1,000,000	-	-

Table 2: Cleanroom classification table comparing the Federal Standard to the ISO Standard. There is one more ISO class (9) which is considered "office space".

1.2.3 Climate, Temperature and Humidity

Temperature control is important for several reasons. One is the strong influence of temperature on most chemical reaction rates. This becomes most evident in wet chemistry processes and the use of resists and developers in lithography. Another aspect is the thermal expansion of materials, which may affect critical distances; in stepper or e-beam lithography exposures, for example. These tools are therefore often equipped with special climate control chambers.

Accurate control of humidity and water absorption is fundamental to reproducible viscosity in spinning processes that use photo and e-beam resists. Some cleanroom climate control systems operate at relatively low humidity levels, which may call for extra precautions to prevent electrostatic discharge problems (see Section 1.2.5). Accurate humidity control, requiring active humidification, is frequently applied only to the most sensitive areas, such as photolithography, whilst the humidity in other areas is kept below an upper limit. It is also important to note that temperature and humidity should be kept at an appropriate level for the comfort of those working in a cleanroom.

1.2.4 Vibrations

Vibration is especially harmful in processes in which small structures are patterned or inspected; lithography exposure, electron microscopy, scanning probe microscopy and the like. Vibration is generally reduced by increasing the mass of the structure in combination with soft damping and vibrational isolation. Since local conditions vary, different vibration reduction solutions have been chosen for the various Myfab cleanrooms:

- In Gothenburg and Stockholm, cleanrooms are firmly attached to the bedrock with piles or mild steel pillars.
- In Lund, the cleanroom provides three independent anti-vibration platforms made from heavy metal plates resting on air-filled dampers.
- In Uppsala, the bedrock was too deep so the cleanroom was fixed to a "concrete block" floating in the clay.

1.2.5 Static Electricity and Electrostatic Discharge

Differences in electrical potential between two objects may lead to an electric current when the objects come into contact, or a spark when they come close to each other. Electrostatic discharge (ESD) may cause severe damage to electronic devices and precautions should be taken to avoid building up electrical potential differences. This is achieved by earthing material, tools and workers in the labs.

Floor, walls and ceilings should have a conductive surface and surfaces and tools should be earthed to the same electrical potential. Lab users should wear garments of fabric woven from conductive fibres. Work benches in sensitive areas may be covered with ESD mats, which similarly dissipate any charge gradually. The risk of ESD damage may be reduced by using ion generators, ionising the air to neutralise charge accumulated on insulating surfaces. Another option is to maintain relatively high humidity and let the moisture dissipate any electric charge.

1.3 Media and Support Systems

1.3.1 Ventilation

The cleanroom ventilation system is one of the most essential elements of particle reduction and climate control. In most cases, this consists of three parts: make-up air (outdoor air), air circulation, and exhaust ventilation (exhaust fumes from equipments and so on) as illustrated in Figure 3.

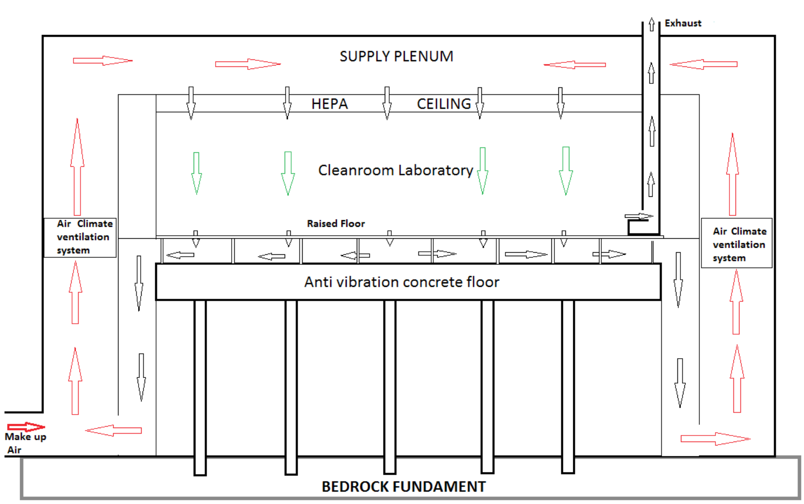


Figure 3: Typical cleanroom air circulation system.

Circulation fan units supply air to the cleanroom through high-efficiency particulate air (HEPA) filters, or ultra-low penetration air (ULPA) filters. Located in the cleanroom ceiling, these filters remove particles from the air drawn from the cleanroom after it has been pre filtered and temperature/humidity-regulated in the fan units. Moreover, the cleanroom is kept at an overpressure to prevent the inflow of non filtered air.

Exhaust ventilation is used to remove harmful fumes and excess heat. The main exhaust flow is through fume hoods, wet benches and tools which use toxic or flammable gases, often at high temperature. All Myfab labs have two or more separate exhaust systems; one system for corrosive applications, another for non-corrosive. Some tools may be connected to a toxic exhaust. In case of a power failure, the exhaust fans are normally powered by a backup diesel generator. Some labs have automated distribution of exhaust capacity as required via utilisation points. Others have static positions on their dampers.

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 requiring an exhaust, and which are fitted with alarms or interlocks, must not be tampered with or operated if an exhaust failure is indicated. Without compensation, the exhaust ventilation would generate a net loss of air in the system. Make-up air is the addition of pre-conditioned and pre-filtered outside air added to the recycling flow. The amount of make-up-air should exceed the total exhaust flow to also compensate for the air leakage and maintain an overpressure inside the cleanroom. Depending on design, classification and so on, the overpressure may be in the range of 5-40 Pa.

1.3.2 Gas Distribution - House Gas and Special Gas

A gas that is delivered through a piping system from one gas bottle or tank installation to several utilisation points in the facility is a house gas. All Myfab laboratories distribute nitrogen (N_2), oxygen (O_2) and hydrogen (H_2) from supplies located outside of the main building in which the cleanroom is located.

- Nitrogen is used as a process gas, technical gas (in dry pumps, for shaft purging in spinners, etc.) and for blow guns, rinsers/dryers, etc. As purity requirements differ greatly between applications, parallel N_2 lines are common. The N_2 is supplied from a cryogenic tank with liquid nitrogen (LN2), fed through evaporators and distributed inside the cleanroom. Depending on purity requirements, in-line filters and other, more advanced, purifiers are installed for the most demanding process applications.
- Oxygen is used as a process gas in dry etchers, oxidation furnaces, etc. For any facility with moderate consumption, the O_2 is drawn from gas bottle.
- Hydrogen is a typical carrier gas in epitaxy processes and a process gas in wet oxidation processes. H_2 may be supplied from gas bottles or a H_2 factory.

Depending on the activities and needs in a specific cleanroom, other house gases may include:

- argon (dry etchers and sputtering tools, or in processes where nitrogen is not inert),
- silane (silicon precursor in deposition processes),
- hydrides such as arsine and phosphine (metalorganic vapor phase epitaxy and aerotaxy),
- helium (a technical gas and less commonly, a process gas).

A special gas is a tool-specific, or locally installed, process gas, usually with high standards of purity. Most special gases are either etchant gases, or precursor gases for elements in deposition processes.

In some cases, LN2 is needed for cooling. This is available to users in some Myfab laboratories (see local conditions). Only Dewar vessels may be used, due to the high evaporation rate from open containers. The LN2 suppliers remotely monitor the tank levels, delivering more LN2 as needed.

1.3.3 Deionised Water

Deionised water (DI water) is available at almost all process benches. It is also known as demineralised water, as its mineral ions (such as cations from sodium, calcium, iron and copper, plus anions such as chloride and bromide) have been removed. This causes the resistivity to increase and provides a convenient measure for the degree of deionisation; ultrapure deionised water has a theoretical maximum resistivity of 18.31 MΩcm. Cleanroom processes require large amounts of DI water (> 18 MΩcm), which is normally distributed from a tank in the media basement. In addition to processing, a lot of DI water is often used to humidify the air supplied to the cleanroom in the colder times of year.

The DI water is distributed to the various points of use from a loop through the cleanroom. By maintaining a continuous flow in this loop, conditions for bacteria growth and particle generation are suppressed. Particle levels in the loop are further reduced by a particle filter.

1.3.4 Electrical Power

Cleanroom operation requires a lot of electricity. Major power consumers are the ventilation system and some process tools, such as furnaces.

In case of a power failure, a diesel-powered emergency generator should ensure continued power supply to important systems, such as exhaust fans, sensors for toxic or hazardous materials and alarm systems. The emergency power cannot supply power for continued tool operation, but some instruments (such as e-beam lithography tools) may be connected to an uninterrupted power supply (UPS) for safe shut-down.

1.3.5 Compressed Dry Air and Vacuum

Compressed dry air is mainly used for pneumatic valves and safety functions at the process benches. Tool or house vacuum is used for spinners, chucks, vacuum tweezers and so on. Vacuum cleaning in the labs is by means of a central vacuuming system.

2 ADMINISTRATIVE GUIDELINES

2.1 Laboratory Access

2.1.1 Preparations and Application

The basic administrative conditions for academic user access may differ between Myfab labs, but for commercial users there must always be a formal contract between the user company and the selected Myfab site. For a new user or group starting on a new project, a common practice is to offer a preparatory meeting with lab staff to verify that the project is feasible and resolve any practical issues. Once the formal and practical preparations have been made at research group/corporate level, individual users may apply for access electronically on Myfab LIMS.

Applicants should normally have approval from their supervisor. It is also highly recommended (and in some cases required) that a "practical coach" is assigned to the user applicant. In well-established user groups, this should be someone internal, but other solutions may be needed for small or inexperienced groups. Information about the project, supervisor, contact data, and other details must be completed on the Myfab LIMS homepage before work commences in the cleanroom.

2.1.2 User Introduction

All new users must attend a set of introductory lectures, lab tours and on-site demonstrations so they know how to work safely and efficiently in the cleanrooms. This training is given by cleanroom staff and covers the basics of cleanroom practices, chemical safety, emergency systems, evacuation plans, cleanroom infrastructure and administrative tools such as Myfab LIMS. Alongside this manual, the user introduction should provide all the necessary basic knowledge for safe and thoughtful use of the labs.

Once the user introduction and all necessary authorisations are complete, the user's lab access keycard will be activated. The new user is then free to enter the cleanroom unescorted, but must not use any tools until the appropriate operator licences have been obtained according to the instructions in Section 2.2.1.

Figure 4: Cleanroom introduction course.

2.1.3 Access Suspension, Termination, and Reactivation

User access is normally valid until the user or supervisor informs the lab staff that it should cease. If a user subsequently requests reactivation of their access, the procedure generally depends on the duration of inactivity. Users remain registered in Myfab LIMS (so no need for a fresh application) and, if the break has been short, immediate reactivation is normally possible. However, after a longer hiatus (or inactivity) users must repeat all introductory training needed for lab and tool access.

Safety violations and bad practices can lead to suspension or even termination of user access. The lab management reserves the right to decide in these matters.

2.2 Tool Access

2.2.1 Operator Training and Operator License

Laboratory access is merely a permission to enter and be present in the cleanroom. To use the instruments, a user must receive training and obtain an operator licence for each tool needed in their project. Some restrictions may apply to specific user categories (such as undergraduate students), type of activity (such as wet chemistry), and working outside office hours.

Operator training is provided by those responsible for the tool in question or a designated instructor in the specific instrument. Names and contact data are available in Myfab LIMS and training is scheduled mutually by the instructor and user. Depending on the complexity of the tool, the duration of operator training may be anything from under an hour to several hours. Sometimes, longer training sessions are divided into several sessions covering demonstration, hands-on training and a final test. The person responsible for the tool is fully authorised to issue (or not) the requested licence, once the training is complete.

New users, particularly in large and established research groups, are encouraged to get acquainted with the most complex or advanced tools and processes before they apply for the corresponding licences. This can be done by repeatedly joining and watching an experienced group member operating these tools. This will by no means replace the formal training with the appropriate instructor, but the time required for this can be significantly reduced

You may apply for a licence on LIMS, or contact (e-mail, phone or directly) the person responsible for the tool and suggest a time for training. The following information should be provided:

- your background and previous experience;
- the name of your research group and supervisor;
- the planned use of the tool.

During your licensing session, you will be informed of all practical details relating to handling of the tool. You will then be registered to go on using this tool on your own.

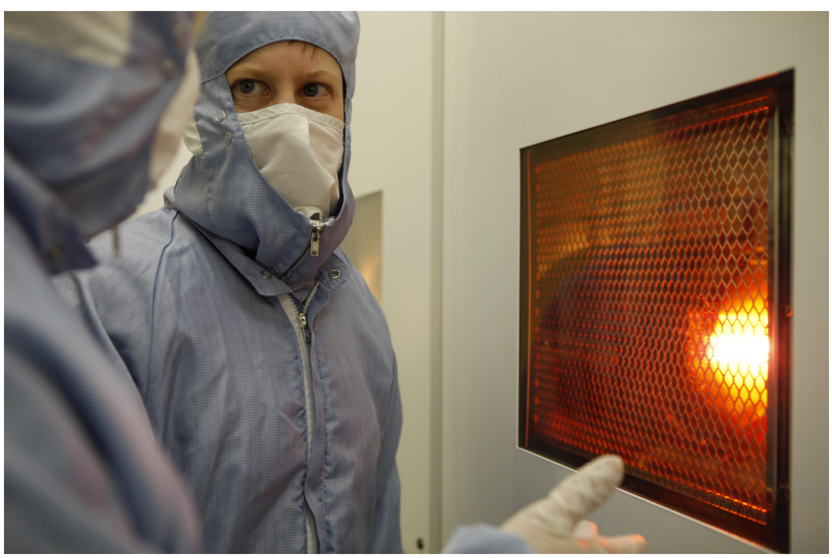


Figure 5: A new user receives operator training.

2.2.2 Tool Booking and Logging

An operator licence is permission to operate a specific tool. It also means the tool will be available for that user to book in Myfab LIMS. Booking is compulsory for all major equipment; failure to do so is a serious violation and may result in your suspension. To optimise availability and efficiency, booking restrictions may apply and allocation to individual users may be limited.

Some labs have compulsory logging of tool sessions. This will always apply when user-fee is based on logged usage time of the tool. However, we always encourage users to log their activities. Even a brief "OK" may prove valuable in a subsequent troubleshooting situation.

User, engaged in several projects, must carefully book the work performed in Myfab LIMS on the correct project. This is especially important for institute or industrial project (i.e. for all commercial projects), since the user fees differ. If samples or materials produced in Myfab is to be sold, the corresponding project must be an industrial project.

2.2.3 Tools at Other Myfab Laboratories

As an active user at one of the Myfab labs, you will have our entire infrastructure at your disposal. Brief information on available resources appears in the equipment list for each laboratory. Typical situations where there is a need to use resources at other labs might be that a requested tool is down for repair (backup), or that the required capability is not offered (complement) by the base laboratory. Whenever there is a need to use external resources, your first step should be to look into opportunities offered by other labs within our infrastructure. The equipment lists (accessible through Myfab LIMS) provides an initial overview, but a final decision often requires a direct, in-depth discussion with the person responsible for the required tool at the receiving lab (see equipment list). Resources outside your base node may be reached on-site or remotely.

On-site access is to be preferred for extensive or repeated use of a secondary site. In this case, the user should attend the site-specific user introduction in order to gain access to the lab. With the relevant operator training and operator licences, the users will be allowed to book the tools they need.

The remote access option is normally recommended for urgent (backup) or isolated activities, evaluation trials and standardised processing. In this case, the work is done by a staff member at the secondary site and the user does not need to be active at this lab. The user may simply choose to specify the process and send the material to be processed. Alternatively, the user may bring the material in person, if presence on-site is deemed important. In this case, however, the user may only enter the secondary site as a visitor, and must be escorted at all times. A few processes have been standardised to a level which makes remote access very straightforward; optical mask generation and ion implantation, for example.

2.3 Language

English is the language used in all Myfab laboratories. It is therefore an absolute requirement that all users must have a good knowledge of this language and proven ability to communicate in speech and writing. Any failure to do so may compromise lab safety. Management will deny lab access to applicants who lack adequate communication skills.

2.4 Acknowledgements to Myfab

All Myfab users benefit from having access to state-of-the art laboratories, and we all need to communicate and explain to a wide audience the importance of support to Myfab, in order to maintain and develop quality and service of the national research infrastructure.

The Swedish Research Council supports Myfab through an operations grant, which also subsidizes the academic user fees.

Therefore we request all Myfab users to give acknowledgement to Myfab in their publications of all kinds: articles, letters, conference presentations, poster, thesis etc.

Example - a user which has used all four laboratories:
"Myfab is acknowledged for support and for access to the nanofabrication laboratories at Chalmers, KTH, Lund University and Uppsala University".

3 MYFAB ELECTRONIC INFRASTRUCTURE

There are two websites that support all users within Myfab by offering information and access to equipment:

- Myfab webpage: www.myfab.se
- Myfab LIMS
  - o Electrum Laboratory: http://lims.electrumlab.se/default.aspx
  - o Lund Nano Lab: http://booking.ftf.lth.se/default.aspx
  - o Nanofabrication Laboratory: http://labbokning.mc2.chalmers.se/Default.aspx
  - o Ångström Microstructure Laboratory: http://lims.msl.angstrom.uu.se/default.aspx

Only registered users are allowed to see and use all available information. Registration is via the Myfab LIMS homepage and access is valid for both websites.

3.1 Myfab Website

The Myfab website is the main web portal for new users to access micro/nanotechnology at any of the four largest cleanrooms in Sweden. Those interested may find information on such topics as: process help, training, education, process examples, contact persons and much more. The various ways of working with Myfab are described. These might involve process service or research collaboration, as well as other ways in which Myfab can offer a new user interesting and attractive conditions to "realise their nano-visions". It is easy to check the various platforms in the different infrastructures and see which site might be the best partner for technological support. All equipment at the different sites is easy to find and inspect and there are examples of completed devices and research activities, plus some ongoing activities.

3.2 Myfab LIMS

Tools may be booked through Myfab LIMS, a Laboratory Information Management System developed by Myfab. Myfab LIMS is a platform for the four laboratories within Myfab, but is also used at several other cleanroom facilities in Europe.

You will require a username and password to access Myfab LIMS. These are normally given once you have completed the introduction course. You may also apply for access to Myfab LIMS and a specific laboratory, by browsing to the Myfab LIMS website and entering the required information. Each user must be associated with at least one project which is financing activity in the lab. Each user is placed on an appropriate user level (user, project leader, project manager or administrator).

The main purpose of Myfab LIMS is to help you gain access to lab resources (tool licences, tool bookings) and information about tool management (instructions, tool status, recipes, process control). For this functionality, Myfab LIMS needs to store information about users and tools in its database. For more general booking rules, see section 4.4. Myfab LIMS is also used to administer laboratories (managing of users, tools, licences, runs, finance, invoicing, statistics, processes and so on).

A process, documentation, and run-sheet module is under development and will enable users to document and keep control of their processes and processing. This option will have functions such as process storing parameters and construction of process sheets.

3.2.1 Menus in Myfab LIMS

After logging in on Myfab LIMS, you will see your home screen. A brief list of the tools allocated to the user will be shown in the left-hand column, as well as local information. The menus My Profile, Bookings Calendar and Siblings are shown in the top right-hand corner.

- My Profile: This is where you manage your account info, find an iCal-link for your private calendar, find your project numbers and much more.
- Bookings Calendar: In Bookings Calendar, you can book and see your licenced tools, plus all other bookings for all equipment in the cleanroom, see figure 6. The various tools appear in the top left-hand scroll menu.

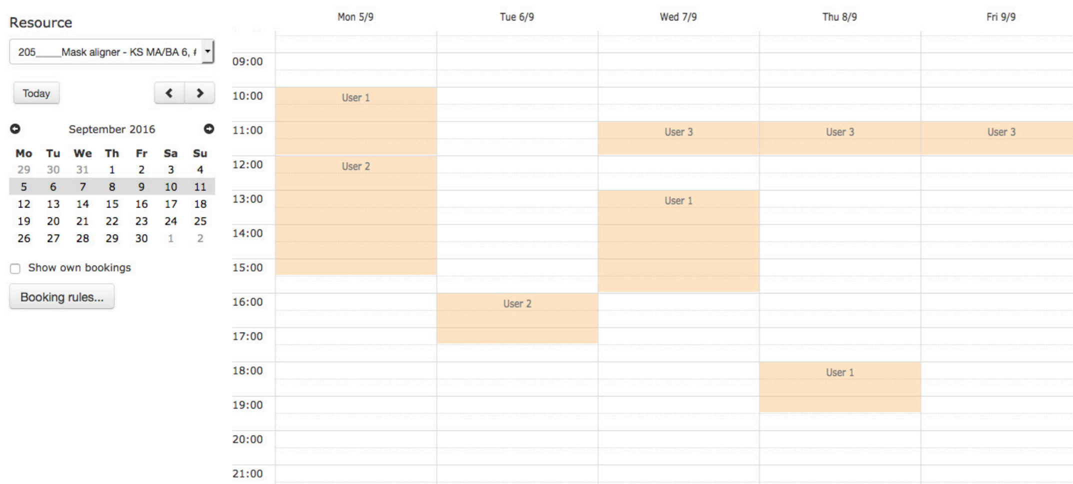


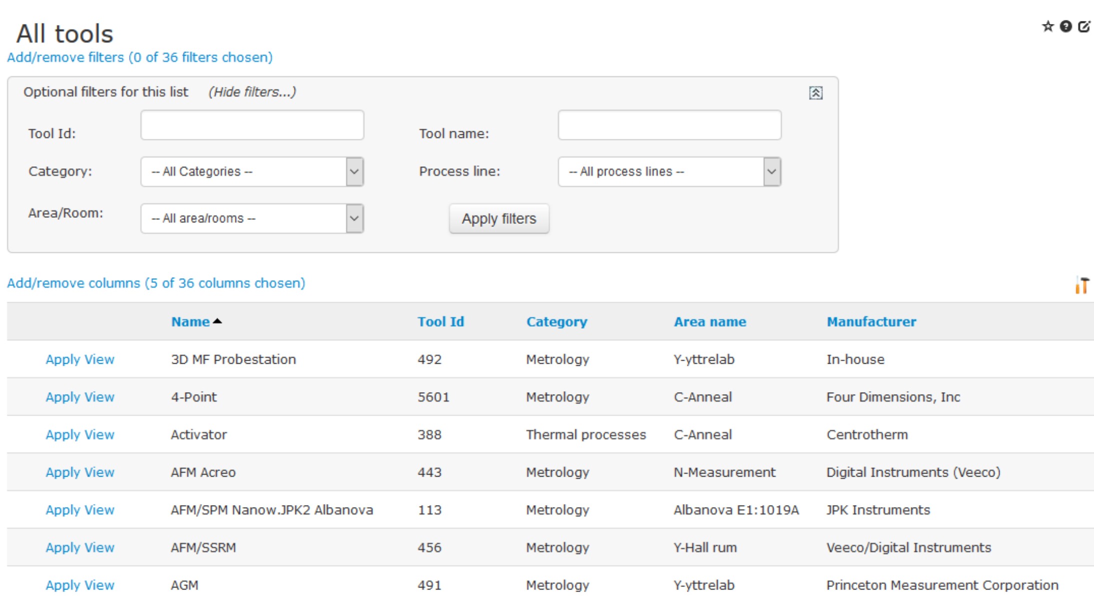
Figure 6: Booking window in the Myfab LIMS system.

- Siblings: By using the Siblings command to change the laboratory you are viewing, you can also see tool and user information for the other Myfab laboratories.

In the top left-hand corner are the three menus for Tools, User, and Info:

- Tools menu: The Tools menu provides all the information about tools, such as booking rules, tool status, logs, personal and tool schedule. Under My Licenced Tools, you can access the bookings calendar and reserve time with your licenced tools, and also see who is tool responsible. There is also technical information and operating procedures. Under All Tools, you can apply for new licences for tools which you have not yet a licence for, see figure 7.
- User menu: In User Menu, the user personal data is stored under My Profile, and should be kept updated with e.g. e-mail address, telephone number, photo etc. by the user. You can also find contact information and send messages to other users of the laboratories, and view statistics of your tool bookings.
- Info menu: This allows you to find important information, such as a list of chemicals used in the lab.

There are additional items for those responsible for a tool, and/or projects.



	Name	Tool Id	Category	Area name	Manufacturer
Apply View	3D MF Probestation	492	Metrology	Y-yttrelab	In-house
Apply View	4-Point	5601	Metrology	C-Anneal	Four Dimensions, Inc
Apply View	Activator	388	Thermal processes	C-Anneal	Centrotherm
Apply View	AFM Acreo	443	Metrology	N-Measurement	Digital Instruments (Veeco)
Apply View	AFM/SPM Nanow.JPK2 Albanova	113	Metrology	Albanova E1:1019A	JPK Instruments
Apply View	AFM/SSRM	456	Metrology	Y-Hall rum	Veeco/Digital Instruments
Apply View	AGM	491	Metrology	Y-yttrelab	Princeton Measurement Corporation

Figure 7: Tool information window.

4 RULES AND WORK INSTRUCTIONS

4.1 Cleanroom Entry and Exit

A cleanroom session should be properly planned and prepared. To avoid unnecessary exits and re-entries, be sure you have booked the right tools and ordered the chemicals you need. Before leaving your office to go to the lab, you should remove unnecessary sweaters and the like so that you will be comfortable under your coveralls in the controlled environment of the cleanroom. Do not enter the cleanroom if you have a heavy cold or eczema.

To reduce particle contamination, facial cosmetics should be minimised and smoking should be avoided immediately prior to entering the cleanroom. Exposed watches and rings should be removed if they have sharp edges or are not sufficiently clean.

4.1.1 Dressing and Undressing

The best method of changing into cleanroom garments is one that minimises contamination to the outside of those garments. The example below assumes that a facemask, hood, and booties are being used and requires the garments to be put on from the top down. Some of the suggested procedures may be unnecessary in lower categories of cleanrooms. Equally, further procedures may be added for cleanrooms used to make highly contaminant-sensitive products.

- The entrance to the changing zone may be a line on the floor, a door, a crossover bench, or any combination of these. If a bench is used, footwear should be dealt with as the bench is crossed. Failing that, a cleanroom mat or flooring should reduce the introduction of contamination to the next zone. Be sure to take several steps on the mat.
- Put on a hairnet if required or desired.
- If a hand-washing system is installed, you should preferably wash your hands before handling the cleanroom garments. Other parts of the body, such as hair and face, should not be touched once your hands have been washed.
- If you need a new set of garments, select the right size and ensure that the packaging is free from tears and faulty heat seals.
- Put on a facemask (if required) and hood. Your hair must be tucked in and the studs, snaps or ties at the back of the hood adjusted for comfort.
- Remove your coveralls from their packaging. Unfold and put them on without touching the floor. One way of doing so is to grab both wrists and both ankles of the garment and put in first one leg then the other.

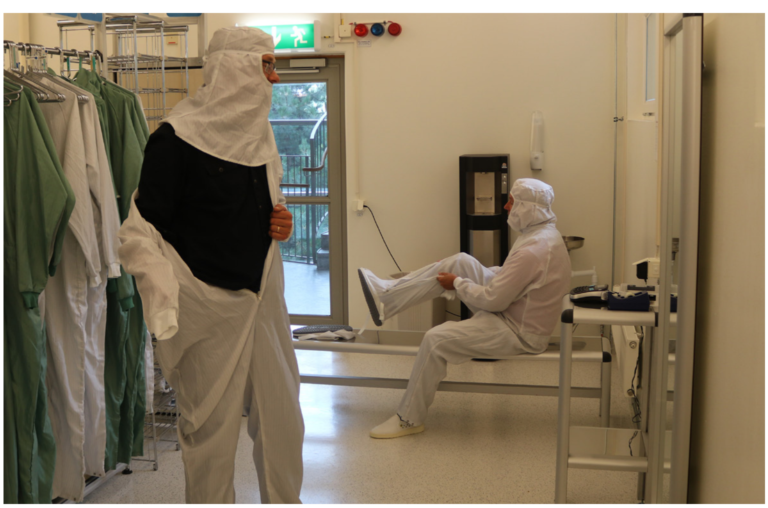


Figure 8: People in the gowning area. It is important to put on the clothing in a specific, proper order.

- Sit on a bench to put on the cleanroom footwear; the legs of the coveralls and the footwear should be adjusted for comfort and safety.
- Check your cleanroom garments in a full-length mirror to ensure they have been put on correctly. Check that the hood is tucked in and that there are no gaps between hood and coveralls. Check that no hair or hairnet is visible. 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 the correct size. If required, protective goggles should be put on (or possibly when entering the cleanroom). These are not only for safety reasons; they also prevent eyelashes and eyebrow hairs from falling out.
- Put on cleanroom gloves, without contaminating their outside. Be sure to grip the gloves at the edge of the cuff and not at the top (the fingers). Gloves should cover your sleeves.

When leaving the cleanroom, you should discard any disposable items such as gloves and hairnet. Hood, coveralls, booties and so on should normally be stored for further usage. If the garments are not to be re-used, they should be placed in a separate container for dispatch to the cleanroom laundry. Cleanroom garments are normally washed once a week.

If the garments are to be reused, they should be removed so that the outside of the garment is contaminated as little as possible. Coveralls should be unzipped and removed using your hands inside the garment to bring it over your shoulders and down to the waist. After removing one leg, the empty leg and arms of the garment should be held to prevent them touching the floor while you remove your other leg. The hood and facemask are removed, and garments to be reused should be stored on hangers to prevent contamination.

Note that cleanroom garments are expensive; it is important to be careful and avoid contaminating them.

4.1.2 Bringing Materials into the Cleanroom

Samples to be processed or characterised, cleanroom notebooks and other personal belongings are frequently brought into cleanrooms. All such items must be cleaned prior to lab entry. Wipes and cleaning solution for this are provided at the lab entrance. Each user who brings material to be processed or characterised using any of the lab tools must ensure that its composition, any previous processing and its cleanliness conform to the lab and tool regulations.

Common materials such as paper, pencils, and fabrics made from natural fibres are normally banned. Cleanroom-compatible equivalents are available. Chemicals and technical tools must be approved by the lab staff before they may be taken into the cleanroom.

If a user is at all uncertain, lab staff should be consulted.

4.2 General Cleanroom Rules

As a user in a Myfab cleanroom, you are responsible for maintaining a good environment in cooperation with hundreds of other users, working in various fields and with different requirements. To make this possible, certain basic rules and guidelines must be observed by all users at all times. For example:

- No beverage or food, including snuff and chewing gum, are allowed in the cleanroom.
- Avoid rapid movements.
- Avoid touching any clean surfaces, such as loading stations.
- Avoid crowding in one part of the room, as this will increase local contamination.
- Do not scratch yourself through your garment, as this will increase particle generation.
- Avoid talking when you are close to sensitive objects (such as samples or tool components).
- Do not carry sensitive objects close to your body. Keep them elevated and in front of you.
- All components or products stored in the cleanroom must be covered, preferably in closed containers. Please note that long-term storage is not allowed in the cleanroom.
- Wet or soiled garments have substantially reduced filtering effect and must be changed immediately.

4.3 General Work Procedures

Any user with access to the cleanroom is free to enter all common lab areas and book and operate all instruments for which he/she has a valid operator licence. Service areas and lab areas dedicated to specific user groups should not be entered, unless there is a specific need and explicit permission has been given.

Users or user groups with a temporary need to bring experimental setups into the cleanroom must have prior approval from the lab staff and be allocated a specific location.

A vital condition for maintaining a good cleanroom environment, is that all surfaces (floors, benches, equipment and so forth) must be kept clear of all nonessential material. All objects must be stored in suitable, dedicated locations when not being used. Any individual setup which is left unattended and not associated with an ongoing booking in Myfab LIMS, must be approved by the lab staff. A note should also be posted, informing other users regarding contact data and start and stop times. Any items left in common areas which do not comply with this instruction may be removed by lab staff, with no compensation for loss or damage.

4.4 Tool Operation

All tools available in the cleanroom and throughout Myfab are listed and described in Myfab LIMS. Each tool has a responsible person who maintains it and supports its users. To become a user of a particular tool, you should contact its responsible person (see LIMS for contact data) regarding operator training and licensing. As soon as an operator licence has been issued, you are free to book and run that tool. However, you are still obliged to consult lab staff if you are not fully confident in operating the instrument.

Unauthorised tool usage may damage an instrument as well as posing a safety hazard. It is also important to know the specific uses of a particular tool and any restrictions that may apply. This will avoid such thing as contamination issues (especially important in high temperature, vacuum and plasma processing). The operator training covers all these issues, including cleaning and other procedures after use and should prepare the licenced user to operate the equipment according to high standards of safety and quality. Nevertheless, please note that the operator licence is only a permit to use the tool according to established procedures and stated instructions. Short-term users may not qualify for training and licensing on some of the more complex and demanding tools.

The following rules apply to equipment use in the Myfab laboratories:

- A lab user is only allowed to operate tools for which he or she has been trained and registered as a licenced user in Myfab LIMS.
- If a tool has compulsory booking requirements, reservations must encompass the entire user session. This should include time for preparatory setup and subsequent cleaning or resetting to idle state.
- If booking is optional, a user who has not made a reservation must leave the instrument if requested by another user with a valid booking.
- As a general rule, a booking is invalidated if no activity has started within 30 minutes from the scheduled start time. If no attempt to cancel the reservation is made, it will be charged. Another user may then use the tool under certain conditions specified by the local site.
- Any tool operation that is not in strict agreement with written and oral instructions communicated to the user must have prior approval from relevant lab staff.
- Any request to develop new processes, introduce new material combinations, modify hardware or change tool settings (if not explicitly allowed) must be approved by the relevant responsible person. This is also required for longer process runs or high consumption of gases and/or chemicals.
- Simple troubleshooting, as described in the tool instructions, may be carried out by a licenced tool user. Other problems, or when a repair is needed, must be reported immediately to the relevant responsible person.
- If required, tool sessions should be logged in Myfab LIMS, or in a separate logbook, with relevant information about what was done and how the tool or process performed.
- After use, the tool should be left clean and in its idle state, ready for the next user.
- Users are responsible for familiarising themselves with all updated information and revised instructions available through Myfab LIMS. It is particularly important to search actively for updated information if you have not used a tool for a long time (several months).

4.5 Processes and Process Integration

Most of the tools provided by Myfab are intended for material processing. In an extensive process sequence, one tool session is often equivalent to one process step. Important process tools within Myfab should have well-defined and documented standard processes. These should be used for equipment qualification and be designed to meet the needs of frequent users. However, a specific project may require development of a new process, or modification of an existing one. This is normally done by the user after approval from the relevant responsible person.

4.6 User Specific Lab Area, Equipment and Material

Depending on available capacity, some Myfab laboratories make surplus cleanroom space available for user groups to rent. Access to these areas may be restricted for regular users. As an integral part of the cleanroom, however, all regulations intended to maintain a safe and high-quality environment also apply to these areas.

4.7 Working Outside Office Hours

Working alone in the cleanroom is strictly prohibited. This means that all lab activities outside normal working hours require the presence of at least one additional approved user, known as a "lab buddy". Users who intend to work odd hours should notify the lab staff of their attending lab buddy. When the activity in the cleanroom is limited to only two users, each person has a mutual responsibility for the other and must coordinate their work in, and exit from, the lab.

Your lab buddy must be an experienced and approved user. Lab buddies must be present in the lab so that they may assist you in the event of an accident. For this system to work effectively, lab buddies must maintain close contact with each other (NOT by mobile telephone). Your lab buddy should be nearby, especially if you are about to use chemicals in the wet benches outside normal working hours. Additional procedures and restrictions may be applicable to special tools. You will be informed of this when you get your tool licence training. Prior lab experience is a requirement of those who want to work outside office hours. We strongly recommend that you work during normal office hours.

Please be aware that local rules may apply at individual Myfab labs.

4.8 Visitors

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

5 WORK ENVIRONMENT AND SAFETY

5.1 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, operate at high temperatures or voltages and so on; conditions that pose a risk to the health and wellbeing of those operating the equipment. Myfab recognises that expertise in specific processing must be combined with necessary understanding of relevant risks in the working environment. The expertise of those working in the Myfab laboratories is the basis of a safe working environment.

Myfab laboratories must comply with all Swedish laws on the working environment and keep track of any new or amended regulations notified by the Swedish Work Environment Authority. A guiding principle to be observed in all Myfab laboratories is that it should not be possible for a single mistake or error to cause an accident. This simple but effective statement has been applied in drafting specific rules for various lab situations:

- Tools used to handle toxic substances at elevated temperatures, or explosives or flammable gases must be constantly supervised on-site.
- New and potentially dangerous processes must be approved by the laboratory management.
- Repair or modifications of tools must be performed by authorised personnel.
- Potentially hazardous work is recomended to be conducted during office hours.

If, despite preventive measures, an incident, or accident occurs then this must be reported to the laboratory staff for investigation. This is to prevent similar occurrences from taking place in future. An incident or accident report should be written according to the rules of the relevant laboratory. Moreover, to avoid potential accidents, all our users are encouraged to inform lab staff whenever any dangerous practices or situations are observed. Myfab will never allow procedures or processes if these entail scenarios which, in the event of a mistake or accident, might have severe consequences.

5.2 Risk assessment in the work environment

Work environment risks are based on the probability of unintentional and undesirable events, relative to subjects or activities in the cleanroom environment which could negatively impact health.

A negative outcome of an event in an economic context is simply net loss of money, but impacts on health or environment are more complex to measure or rank by severity. It is generally accepted that injuries, which cause severe pain for a long period, have permanent impact on the quality of life, or prove fatal, are severe consequences. Preventive actions must be taken to reduce either the probability of such an accident (change of procedure, modification of equipment and the like), or its consequences (for example using protective gear, detecting harmful chemicals).

The wet bench might serve as an example: These offer good protection against airborne chemicals, but no protection against splashes. A splash may be produced by simple handling mistakes, such as dropping an item into a container. The probability of such an event is not negligible, but the consequences can easily be reduced by using proper face-protection.

Swedish law requires a risk assessment for any work involving hazardous chemicals. The practical procedure for conducting a risk assessment is different in the various labs, but they all include a study of the Safety Data Sheet (SDS) of chemicals and/or gases to be used, and filling out the risk assessment form in KLARA.

The risk assessment must be approved before any actual work with the chemical is started. Any modification of a chemical experiment (such as changing a temperature or concentration) must be reflected in an updated risk assessment.

Concerning long-term effects of inhalation or skin exposure, the threshold limit value (TLV) for airborne chemical substances is defined as a maximum concentration in parts per million (ppm). Three types of TLVs for chemical substances are defined:

- Threshold Limit Value - Time Weighted Average (TLV-TWA): Average exposure based on an 8h/day. 40h/week work schedule.
- Threshold Limit Value - Short Term Exposure Limit (TLV-STEL): Spot exposure for a duration of 15 minutes. that cannot be repeated more than four times per day.
- Threshold Limit Value - Ceiling (TLV-C): Absolute exposure limit that should not be exceeded at any time.

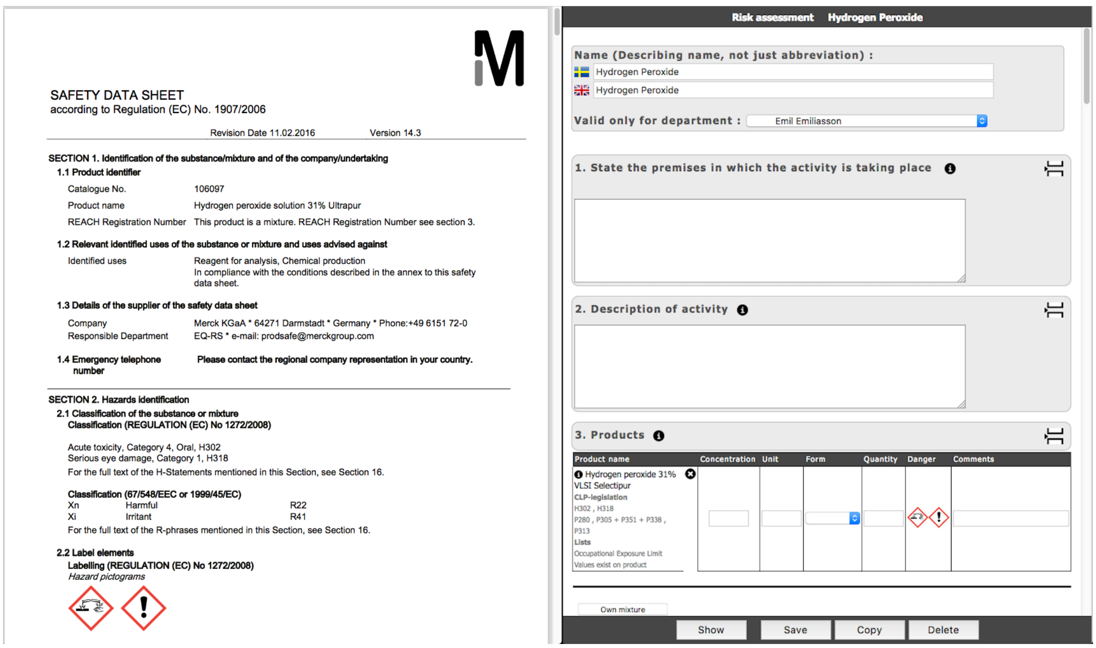


Figure 9: Reading the SDS and conducting a risk assessment is important in all types of chemical work.

5.3 Work environment risks

5.3.1 Chemicals

A major working environment risk is exposure to hazardous chemicals. Chemicals are therefore deemed the most critical hazard to users in a cleanroom facility. Chemicals can be of different types, corrosive, toxic, flammable etc. and in different states, solid, liquid or gaseous. The most common chemicals in a cleanroom are liquids and gases. A more extensive explanation of liquid chemicals, waste management and safety can be found in Chapter 6.

5.3.2 Harmful solids

Some of the metals and semiconductors used in cleanroom processes are harmful and should be treated with great caution. Always read the SDS before use! Harmful solids include:

- Nickel (Ni): shows limited evidence of carcinogenic effects but may cause sensitisation by skin contact.
- Chrome (Cr): highly toxic in contact with skin and if swallowed. Also harmful if inhaled.
- Indium Phosphide (InP), Gallium Arsenide (GaAs), and other compounds and elemental semiconductors: these are toxic elements and require dedicated processing and waste handling.

Important rules when working with harmful solids and contaminated tool parts:

- Always wear protective gloves and visor/goggles. Avoid direct contact with skin.
- Take precautions against dispersal and accumulation of particles. Work in a fume hood or use a respirator.
- Solid residues and/or contaminated tool parts that are being replaced (boats, shields and so on) should be treated as hazardous waste.

5.3.3 Process gases

Various dangerous gases are used in the cleanroom. Toxic, corrosive and flammable gases are used in various applications. There are two main risks arising from hazardous process gases:

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

Cabinets, distribution boxes, and point-of-use boxes that contain toxic, flammable, or corrosive gases are connected to exhaust ventilation. One or more gas detectors are also installed in each unit. Any leaks detected will be displayed on a monitor and, if necessary, trigger evacuation alarms. For some tools, gas distribution (target gas and concentration-dependent) may also be interlocked.

5.3.4 Electrical hazard

Our cleanrooms are fitted with a vast array of electric tools and power consumption per square meter of cleanroom is significant. Accidents involving electric shock may result in anything from discomfort to instant death. Current strength and path through the body determine the outcome of an electric chock. An electric current passing from hand to hand or hand to foot will most likely prove fatal if in the range of 50-500 mA. Higher currents do not normally kill instantly, but will burn internal and external organs.

5.3.5 Fire hazard

Within a given area, the combination of chemical use, flammable process gases, high density of electric tools and tools operating at higher temperatures all increase the risk of fire.

A fire is a very serious matter and fire prevention must always be a priority. As there may be toxic gases and chemicals present, a fire can have serious consequences for a cleanroom and its occupants as well as the surrounding environment. Our facilities are equipped with automatic fire alarms, smoke detectors and sprinkler systems.

5.3.6 Laser Radiation

Some tools utilise laser radiation. Laser radiation causes instantaneous damage if the eyes are exposed to it and the incoming radiation is sufficiently intense. This means that eyes may be damaged by direct reflection of low-intensity laser beams or diffuse reflection of high-power ones. The radiation is not necessarily in the visible spectra so always be sure to protect your eyes with laser safety glasses or a face shield. As well as the risk to eyes, short and long-term effects like burns or cancer may result from (prolonged) skin exposure.

Lasers are usually labelled with a safety class number, which indicates the danger level:

- Class I/1: Inherently safe, usually because the beam is enclosed.
- Class II/2: Safe during normal use; the eyes' blink reflex will prevent damage. Usually up to 1 mW power.
- Class IIIa/3R: Usually up to 5 mW. There is a small risk of eye damage within the blink reflex time. Staring into the beam for a few seconds is likely to cause (minor) eye damage.
- Class IIIb/3B: Can cause immediate severe eye damage upon exposure. Usually lasers of up to 500 mW.
- Class IV/4: 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 powers above are for visible-light, continuous-wave lasers. Other power limits apply for pulsed lasers and invisible wavelengths. If possible, the path of the beam should be covered. People working with class 3B and class 4 lasers must protect their eyes with safety goggles designed to absorb light of a particular wavelength.

Rooms with laser applications have yellow/orange warning lights above their entrance door. When the lights are on, the laser is in use. Do not enter!

5.3.7 UV Radiation

UV light sources are common in areas where lithography processes are carried out. One of the problems of working with UV radiation is that the symptoms of overexposure are not immediately felt. Those exposed to UV radiation might not realise the hazard until after the damage has been done. People working with UV light must therefore protect their eyes with safety goggles designed to absorb light of a particular wavelength. There are 3 classes of UV light:

- UV-A (near UV): Lowest damage potential, with wavelengths in the 320-400 nm range. Damage from high exposure may be cataracts.
- UV-B (mid UV): Mid to high damage potential, with wavelengths in the 290-320 nm range. Damage from high exposure is skin and eye damage and an increased risk of cancer.
- UV-C (far UV): Highest damage potential, with wavelengths in the range 190-290 nm. Damage from high exposure is skin and eye damage.

5.3.8 X-ray Radiation

X-ray is a high-energy electromagnetic radiation with wavelengths of 10 to 0.01 nm and energies in the 120 eV to 120 keV range. They are shorter in wavelength than UV rays and easily penetrate many materials.

This type of radiation is emitted from diffractometer tools and ion implanters, among other things. These tools are normally shielded, but manipulation of the hardware or an unsafe operation may reduce the efficiency of safety measures and expose personnel to X-ray radiation. The physical consequences of exposure can be mutagenic or carcinogenic.

5.3.9 Cryogens

Liquid nitrogen (LN2), liquid helium (LHe) and solid carbon dioxide (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 cryogenic gloves and designated personal protective equipment against the freezing effects. Under no circumstances should a user get cryogenic liquids on their bare skin; severe injury may result.

All cryogens listed above can displace the oxygen in the air as they evaporate. Therefore, you must only use them in well-ventilated rooms, after analysing the amount of air that might be displaced by use of the proposed cryogen.

The filling process must be watched continuously to avoid overfilling. There is always a risk of suffocation when handling large amounts of LN2 indoors. The evaporated nitrogen may replace much of the oxygen if the room is small or the ventilation insufficient. Major spillages must always be avoided, as one litre of LN2 will turn into over 700 litres of gas when evaporated. Major spillages will also cause severe damage to the floor. Liquid nitrogen is extremely cold, 77K (-196 °C) and may cause severe injury by freezing skin and underlying tissue. It is especially dangerous if LN2 is spilled into a confined space, such as the inside of your shoes or gloves, or splashed into your eyes.

5.3.10 Nanomaterials

Nanomaterials are materials smaller than 100 nm in at least one dimension, including nanoparticles, nanotubes, and nanowires. Despite there being no consensus on 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 put the nanoscale between microscale (100 nm) and atomic/molecular scale (about 0.2 nm).

The hazards associated with handling of nanomaterials are still under debate. We require our users to keep updated on the potential risks of their materials and take appropriate precautions during handling.

6 CHEMICALS

6.1 Chemical Hazards

Fundamental to the safe use of a given chemical is a knowledge of its properties. This information is available from experienced colleagues, laboratory staff, the person responsible for the tool where the chemical is used and, in particular, from the supplier's SDS. Only chemicals that are approved by the laboratory management may be used in the cleanroom.

If a new chemical is needed, a request together with the supplier's SDS and details of how this chemical will be used safely, should be presented to the appropriate lab staff.

If the chemical has dangerous properties and the laboratory management concludes that the risks cannot be reduced by using suitable tools, procedures and protective gear, then processing involving that chemical may be prohibited. Similarly, Myfab will not allow use of dangerous or environmentally unfriendly chemicals if there are better alternatives. All our laboratories are working to find less dangerous alternatives for the chemicals used.

Hazardous properties for chemicals should be marked on bottles using a special set of pictograms. The pictogram symbols have been revised in recent years, so different pictograms may apply. The current chemical symbols are shown in Figure 10.

Figure 10: Pictograms for chemical hazards (as of 2014).

The cleanroom supplies a set of standard chemicals as well as non-standard ones. All non-standard chemicals are user or project specific, meaning that the user or project pays for and has the exclusive right to use the chemical. All standard chemicals are of Very Large Scale Integration (VLSI) quality unless the only available grades are not. Below is a description of typical wet chemicals used in the Myfab cleanrooms.

6.1.1 Acids

Acids are corrosive substances and will damage human tissue. The eyes are particularly vulnerable to exposure. Acids may only be used in dedicated wet benches and fume hoods. Acids can cause chemical burns to the skin if exposed. They may also be toxic, cause rapid heating through exothermic reactions (and thus cause thermal burns to the body) and they may even trigger explosions. Some examples include:

- Hydrofluoric acid (HF).
- Hydrochloric acid (HCl).
- Sulphuric acid (H_2SO_4).
- Nitric acid (HNO_3).
- Ammonium fluoride (NH_4F).
- Perchloric acid ($HClO_4$).
- Acetic acid ($C_2H_4O_2$).

Hydrofluoric Acid

HF is essentially a gas dissolved in water. The vapour pressure of HF at room temperature is high and highly toxic, corrosive fumes will be released. The toxicity of HF is due to its fluoride ion content which, when it penetrates the skin, can cause the destruction of deep tissue layers. Chemicals such as HF, NH_4F and mixtures of these (BOE, BHF), may differ in concentration, vapour pressure and volatility, but the fundamental toxicity is the same.

Dilute HF must be treated with the same caution as concentrated HF, as symptoms of exposure may appear anything up to 24 hours later. Ensure that in-date HF-specific safety products are close at hand where HF will be used. It is imperative to go to hospital as soon as possible after an accident involving HF. See section 7.3.4 for more information about chemical safety products.

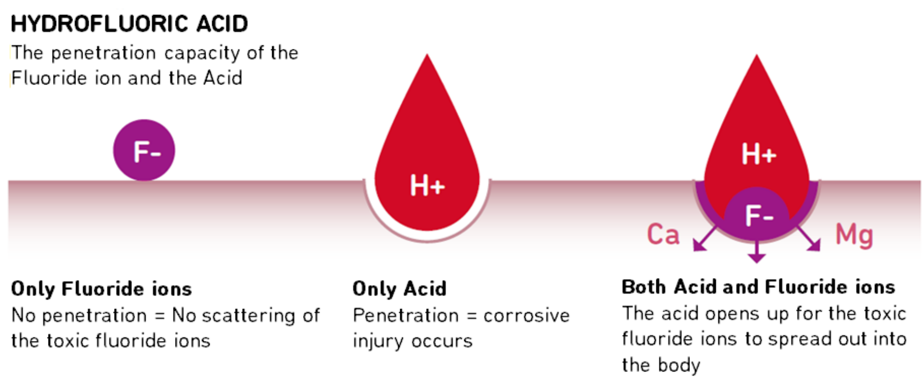


Figure 11: Penetration of HF into the skin, compared to stand-alone H^+ or F^-. Figure taken with approval from Medical Care Systems.

Piranha

Piranha (also known as 7-up) is a mixture of sulphuric acid and hydrogen peroxide. Piranha is used mainly to clean wafers of photoresist residues or other organic contaminants. When mixed, sulphuric acid and hydrogen peroxide creates a highly exothermic reaction and the temperature of the mixture will initially rise to at least 120°C. The hydrogen peroxide will decompose to produce highly reactive oxygen radicals. These radicals will oxidise most species containing carbon and the sulphuric acid is an excellent solvent for oxidised carbon species.

If hot piranha solution contacts the face in an accident, the result will probably be instant, permanent damage to the eyesight and disfiguring skin burns. The solution must be prepared and used with caution, always wearing proper protective gear. Always add the hydrogen peroxide to the sulphuric acid when mixing piranha solution!

6.1.2 Bases

Bases are corrosive substances and will damage human tissue. The eyes are particularly 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:

- Tetramethylammonium hydroxide (TMAH).
- Potassium hydroxide (KOH).
- Sodium hydroxide (NaOH).
- Ammonium hydroxide (NH_4OH).
- Ammonia (NH_3).
- Photoresist developers (typically containing NaOH or TMAH).

Tetramethylammonium hydroxide

TMAH is considered as a very dangerous chemical, and must be handled with the greatest care. In addition to being a highly corrosive liquid, TMAH is very toxic. It can be fatal not only when swallowed but by minor skin exposure. Absorption through the skin is very rapid, so the key to limiting harmful effects is to limit the risk of exposure. TMAH will cause burns to any area of contact. The liquid can produce toxic, corrosive vapours which may cause blindness.

6.1.3 Organic solvents

Isopropyl alcohol (IPA) and acetone are the most commonly used organic solvents in any microelectronic cleanroom. IPA is a general cleaning agent for wafers and equipment. Acetone is used for such things as removing resist and cleaning wafers and resist-contaminated equipment. Health-related risks are fairly low when handling IPA and acetone. However, they are both flammable liquids and should be treated with respect when heating is involved.

Other organic solvents used within Myfab are more or less toxic, carcinogenic or mutagenic. These solvents should always be avoided if less toxic or carcinogenic alternatives are available (for example, ethanol should be preferred before toxic methanol). For some solvents, the health-affecting properties are not known or fully understood. This may also be true for chemicals other than organic solvents; such chemicals should be treated as toxic. Always consult the SDS before starting to use a new chemical. With very few exceptions (such as IPA), the use of organic solvents must be confined to ventilated workstations. For the sake of simplicity, all organic solvents should be considered flammable.

6.1.4 Photoresist and other organic chemicals

Special organic chemicals like photoresists, epoxy resins, and adhesives are also used in the cleanroom. Mostly, these are not as acutely corrosive or toxic as acids. However, if they are handled incorrectly over a period of time, long-term exposure to the skin or respiratory system may result, with known or unknown consequences.

Most photoresists are mixtures of solvents, novolac resins and photoactive compounds. The resulting mixture can be toxic, flammable and/or irritant. Since fumes evolved during use of photoresists, polymers and the like must not be inhaled, these chemicals should only be used in approved ventilated areas.

Dedicated workstations such as spinners or ovens are fitted with exhaust ventilation; if there is any odour then there is a technical problem with the equipment or the handling procedure.

6.1.5 Sensitising Chemicals

Some chemicals are known to induce sensitisation from prolonged skin exposure (H-statement H334) or contact with the respiratory system (H317). Sensitisation is an allergy-like condition with low tolerance to epoxy, and other chemicals and allergens. According to regulations, all users handling sensitising chemicals must undergo training in their use and pass a risk assessment. If the user is to handle certain sensitising chemicals, medical check-ups should be offered. For other chemicals, such check-ups are obligatory. The relevant legislation can be found on the Swedish Work Environment Authority website: www.av.se (AFS 37).

6.1.6 Oxidising agents

Because of their chemical structures and compositions, oxidisers have excess oxygen which may be liberated, especially at higher temperatures. The primary hazard associated with this class of compounds lies in their ability to act as an oxygen source and thus readily stimulate the combustion of organic materials.

Oxidisers are grouped into four classes (see below) based on their ability to affect the burn rate of combustible materials, or undergo self-sustained decomposition.

- Class 1: Oxidising materials whose primary hazard is that they may increase the burn rate of combustible material with which they come into contact (nitric acid <40%, 25% H_2O_2, ammonium persulphate and so on).
- Class 2: Oxidising materials which will moderately increase the burn rate or which may cause spontaneous ignition of combustible material with which they come into contact (nitric acid >40%, sodium hydroxide, sodium permanganate, etc.).
- Class 3: Oxidising materials which will cause a drastic increase in the burn rate of combustible material with which they come into contact or which will undergo vigorous self-sustained decomposition when catalysed or exposed to heat (fuming nitric acid, hydrogen peroxide >52% and so on).
- Class 4: Oxidising materials which can bring about an explosive reaction when catalysed or exposed to heat, shock or friction (perchloric acid>72%, ammonium permanganate and so on).

Hydrogen Peroxide

Hydrogen peroxide is a strong oxidiser and may react violently when mixed with other chemicals. Using hydrogen peroxide in mixtures is therefore limited to mixtures such as piranha solution, or other well-known recipes.

6.2 Protective Gear

Protective gear is available and must be used for all approved processes where such gear is deemed necessary. If it is not available for some reason, then the process may not be used and lab staff should be informed. The need for protective gear for a specific process must be examined before work commences. This is accomplished by reading the written instructions for that process, and/or verbal directions from the instructor of that application.

Protective gear for chemical handling can be:

- goggles or face visor protection,
- chemical gloves,
- apron,
- arm covers or sleeves,
- protective booties.

As a general rule, chemical gloves and face visor/goggles must be worn at all times for all work with wet chemicals. For eye protection, a face visor is preferable to goggles and a protective apron is always recommended.

Figure 12: Typical protective gear for the cleanroom. Different labs use different colours and fabrics, but the principles are the same.

6.3 Routines for handling of chemicals

The following rules apply to all handling of chemicals in the cleanroom:

- Put on chemical gloves and a protective face visor/goggles before starting work with chemicals at the wet benches.
- Inspect your chemical gloves carefully. If they are discoloured or damaged, they should immediately be discarded and replaced. Rinse your gloves carefully before placing them into the rubbish bins.
- If required, put on a chemical apron, sleeves, and chemical protective cover booties.

- Do not introduce previously unknown chemicals without prior approval from the lab management. The purchase of chemicals should be arranged through the lab staff.
- Inspect beakers, labware and so on for damage before use. Discard if necessary.
- Some containers and beakers are allocated to certain chemicals and must not be used for anything else.
- Mixing and use of chemicals is restricted to ventilated work areas.
- Never mix chemicals without prior knowledge of the consequences.
- Use small quantities of chemicals where possible.
- Apply the acid into water rule, known as the "AAA Rule": Always Add Acid.
- Do not disturb people who are working with chemicals.
- Special training and full attention is required when working with hazardous chemicals like HF, piranha and TMAH.
- Chemicals containing HF and KOH solutions may only be used in plastic containers (PP, PE, Teflon, etc.).
- Ensure that flammable chemicals (such as acetone or propanol) are not used near hot surfaces. Even small amounts may cause fire.
- Minimise the heating of chemicals and if necessary, keep well below boiling point. For example, max. 50°C for acetone.
- Open containers containing NH_3 and HCl must not be placed next to each other. The chemical reaction between their vapours will generate solid particles in the cleanroom.
- Chemicals in containers that are not clearly labelled should be disposed of immediately. Mark the container "unknown content" and call the lab staff.
- Some chemicals should be re-used. Pour these back into their bottles and carefully rinse the container with DI water.

6.4 Chemical cupboards

Chemicals and chemical waste must be stored in ventilated cupboards. Only compatible chemicals may be stored in the same cupboard. If you want to store a mixture of different chemicals, please consult the staff in charge for further assistance. Mostly, there are two different types of cupboard assigned to storage of chemicals:

- Acid cupboards: Inorganic acids, bases, oxidising 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.
- Solvent cupboards: These cupboards are assigned to storage of organic solvents only. Solvent cupboards are connected to the solvent exhaust system.

Some cleanrooms have dedicated cupboards for toxins, bases, and photoresists (see local conditions).

6.5 Ventilated Work Areas

Wet benches and fume hoods represent two different technical solutions to the problem of handling chemicals safely. Solutions to this problem should generally incorporate:

- a way to separate the user from any harmful airborne pollutants,
- a surface to work on,
- a way of disposing of chemicals after use,
- a choice of materials compatible with the intended chemicals.

Ventilated work areas are connected to one of two available exhaust systems; acid exhausts in polypropylene (PP) and solvent exhausts in sheet metal (check local conditions). When working at high temperatures or with large volumes of chemicals or fuming chemicals, you must use a fume hood with the correct extraction system.

There are typically two independent drainage systems.

- Acid drainage is used for acids, bases, and DI water. The effluent is drained to a neutralising tank on the level below the cleanroom.

- Solvent drainage is used for organic solvents, with the possible exception of halogenated solvents (please consult laboratory staff). The waste is drained to a waste storage tank.

Keep in mind the following working principles:

- Never use acids or bases on a solvent work area, or vice versa.
- Respect the ventilation guard. If the alarm is on, the ventilated work area is not providing sufficient protection against airborne chemicals.
- Do not place beakers or containers of chemicals closer than 15 cm from the front edge of the work area.
- Beware fire hazards! Flammable chemicals must be handled with caution. Consult the SDS for properties of the chemicals you are handling. Organic solvents are always flammable. Do not leave beakers or containers of organic solvents unattended near possible sources of ignition like electrical equipment, especially not hotplates.
- Think of other users' safety! Clean the ventilated work area after use. Do not leave chemicals, beakers, warm hotplates etc. unattended. If it is necessary to leave before a process is complete, a note with your name, contact information, chemical contents and the date must be clearly visible.
- Keep the bench clear of all unnecessary items that might disturb airflow.

Common functions in ventilated work areas are drain valves, heated chemical baths, ultrasonic baths, etc. These functions are operated from a control panel on the bench front. Protective gloves are used to protect your hands. Always assume they might be contaminated with chemicals. Such contamination should not be transferred to the control panel. Rinse gloves with DI water before touching any buttons on the panel, or handling new beakers.

6.5.1 Fume Hoods

A fume hood is an exhaust-ventilated workspace with a see-through, height-adjustable sash that is designed to protect people from fumes and chemical splashes. The exhaust ventilation constantly draws 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

Figure 13: A fume hood in use. Make sure the sash is below the safety line and that you are wearing the proper protective gear.

room. The sash gives excellent protection against splashes. Typically, fume hoods require airflows in the range 500-800 m^3/h, depending on the hood geometry and design principle.

Most fume hoods are fitted with ventilation guards that monitor the air velocity (directly or indirectly by measuring the pressure in the hood). If the velocity or air volume decreases to an unsafe level, an audible alarm normally sounds.

Keep in mind the following fume hood working principles:

- Low exhaust capacity in the fume hood may be locally induced (sash opened too 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. In other words, position the sash so that you are working whilst looking through it.
- Beware fire hazards! A fire in a fume hood will not initially be picked up by the smoke detectors, since the exhaust effectively removes the smoke. If the fume hood is connected to a PP duct, the fire may propagate through the exhaust ducts.
- The cross-sectional geometry of large containers or pieces of equipment placed in the fume hood may 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 its front. If the object is placed on 5 cm spacers, air will also flow under the object and your protection will improve.

6.5.2 Wet Benches

A wet bench is an exhaust-ventilated work table. The height and depth of the wet bench make it suitable for working in an upright position. The top surface is perforated to allow air flow through the worktable and recessed chemical baths are suitable for handling cassettes of wafers. The baths are covered by lids that flip-up to open. When a lid is open, air flows through an open section surrounding the container.

Some benches have HEPA-filters attached above and around the ceiling area where the bench is located. The filters provide clean air to the bench surface and, if the air supply is in balance with the bench exhaust, vapours are effectively removed. A wet bench offers much cleaner handling of wafers than a fume hood. The latter draws ambient cleanroom air 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 in the baths, but are less effective for chemicals handled on top of the work surface. The maximum safe working height is 200 mm (local regulations may exclude handling of chemicals on the upper 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 carried out with chemicals in the line of sight without any transparent screen between the chemicals and the user. If something is dropped into a container, splashes may reach the user. A face shield / safety glasses is therefore required and an apron is always recommended (in some cases compulsory; consult local rules).

If the perforation in the upper surface is covered by papers, beakers or other items, airflow through the bench will be reduced. As the air supplied to the bench from the filter ceiling is constant this may then exceed the exhaust flow and the excess air will “roll” over the front edge of the bench, possibly carrying vapours from the bench chemicals into the circulating air system.

6.6 Waste management

It is extremely important to use the correct drain or container for your used chemicals, since mixing of these chemicals would create a risk of explosion in the waste-handling facility. All ventilated work areas with their etching and cleaning baths and so on, are connected to the proper waste drain or container. If you have waste chemicals and are unsure about what to do with them, place them in a plastic waste container and contact lab staff for advice. Never discharge any materials in the drains if you are not sure they belong there. Some chemicals should always be collected in waste bottles after use, for final disposal by lab staff.

Information on how a certain chemical should be disposed of is presented in the SDS and a complete register of all chemicals is found in the KLARA database as well as Myfab LIMS.

Leaking chemical containers should be treated as a major safety risk. They may cause severe personal injury and/or material damage, particularly if chemical groups are mixed.

Bear this in mind when your work is completed:

- Warm chemicals must be cooled down before disposal.
- Do not dispose of used chemicals if you are unsure how to do it. Store in closed bottles and contact lab staff for advice. This is particularly applicable to concentrated, unmixed chemicals.
- Users are responsible for cleaning up minor chemical spills. Please contact lab staff if a major spillage occurs.
- Rinse labware and place in its designated place.
- Chemical gloves should be rinsed and put back in their designated place, without touching any surface outside the ventilated area.

Liquid chemical waste, which cannot be poured into the chemical drains or bottles plus solid chemical waste should be removed to the waste storage room for destruction. Chemical waste containers must always be labelled with the owner's name, department, the complete chemical name (not abbreviations or trade names) and the concentration of constituents if the waste is a solution. Make sure you have sufficient information on the compatibility of any chemicals you intend to mix.

Do not mix your chemical waste with that of the others, even if they are compatible with your chemicals. You are only allowed to mix your own chemical waste products and only if they are compatible.

Figure 14: Certain chemicals are classified as environmentally harmful and should be stored in special bottles for destruction. Others may be poured into the sink (local rules).

7 ALARMS AND EMERGENCY

7.1 Alarms

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

- Fire alarms: Smoke detectors, manual activation, sprinkler systems and any heat detectors.
- Gas alarms: Sensors for detecting specific hazardous gases.
- Operational alarms: Faults 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. This is indicated visually by red lights and audible signals from bells, sirens or horns. Fire alarms and certain concentration levels of hazardous gases will trigger the total evacuation alarm. Operational alarms are indicated visually by blue lights (there may also be an audible signal; check local conditions) and do not necessitate evacuation. The total evacuation alarm will not only be signalled to cleanroom users; it will also trigger necessary actions in the infrastructure regarding ventilation, house gas distribution, tool shutdown, and so on. The alarm system and alarm scheme for each Myfab lab are described in the lab specific appendix.

7.1.1 Evacuating the Cleanroom

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

- Without delay, go to the nearest emergency exit and leave the cleanroom. Emergency exits are marked with green and white signs as per international standards. All clean zones have emergency exits in the same room where work is carried out. There are at least two alternative exits from all locations in the cleanroom. When evacuating, do not waste time removing your cleanroom garment; leave it on. Do not delay evacuation by trying to conclude work that otherwise might be spoiled.
- During evacuation, be sure that other users follow your example. Help them, if necessary and possible. If possible, account for the whereabouts of any missing colleagues.
- Go to the assembly point and await further instructions. Do not leave the assembly point unless laboratory staff authorise this action.

Consult the lab-specific appendix for details of your assembly point and what to do after an evacuation.

7.2 In Case of Emergency

112 is the dedicated public emergency number in Sweden for obtaining help from all the emergency services. The SOS Alarm centres are contactable 24 hours a day and co-ordinate dispatch of the emergency services.

When your 112 call is answered, the SOS Alarm operator will ask you questions. 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 in need of police intervention? In the event of an accident, the operator needs to know if anybody is injured and, if so, how many injured people are there and the nature of their injuries. Describe clearly the location where help is needed and tell the operator your name, address and telephone number.

The SOS Alarm operator must have this information as quickly as possible to determine what help is needed and to dispatch the correct emergency service to provide the necessary assistance. The SOS Alarm operator may also need more information while help is on its way, so stay put and remain on the line as long as requested.

In case of a chemical accident, you must give the concentration, volume, and exposure-time of the chemical concerned. This information will help physicians to be well prepared for an ongoing rescue. If medical attention is necessary due to chemical exposure, the SDS of that chemical should be given to the physician. Never go to the hospital yourself, call the ambulance instead!

Actions in case of a serious personal accident

- Give first aid.
- Call for an ambulance. Dial 112.
- Give the address of your location (see local information, or last page in the manual).
- If a chemical accident, also give the chemical name, concentration, volume, and exposure time.
- Assist the injured person and send someone to meet the ambulance and paramedics.
- Guide the paramedics to the injured person.
- It is compulsory for at least one person to accompany the injured person to the hospital, if no lab staff is available, a user should do this.
- It is important that rinsing is continued during transportation to paramedics/hospital, using a handheld bottle.
- If no lab staff is available, contact a relative of the injured. Each group has a register with this information.

7.3 Emergency Aids

7.3.1 Fire Extinguishers

Fire extinguishers are mounted at various locations around the cleanroom. These locations are marked with an additional sign (see figure above). Extinguishers are typically carbon dioxide type due to their non-destructive properties. Cleanroom users are not normally expected to use fire extinguishers, but different rules are in force at the various labs.

7.3.2 First Aid

First Aid boards with basic First Aid gear, band aids and the like, are placed in various locations (not inside the cleanroom). Familiarise yourself with the location and contents of the First Aid kit.

7.3.3 Chemical Safety Aids

After exposure to chemicals, the appropriate action could vary depending on the chemicals involved. Relevant information can be found in the SDS and should be studied carefully for all chemicals you intend using.

There are three types of chemical safety aids. Water based eye and emergency showers, calcium gluconate gel, and the hand-held chemical showers Diphoterine and Hexafluorine. Chemical injuries should always be inspected by a medical specialist.

Emergency Shower

Emergency showers should be used for flushing off chemicals in case of a chemical accident and are available close to chemical handling areas. When handling wet chemicals, you should always be aware of the location of the nearest emergency shower. The proper way to deal with chemical exposure is to start using the shower without removing your clothing. Once inside the shower remove the clothing and continue rinsing. If splashes reach your eyes, it may only be a matter of seconds before there is permanent damage. Hence, eye rinsing must be your first priority.

Eye Shower

The only way to remove harmful chemicals from your eyes and limit the damage 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 it is done. Rinsing should be continued for at least 20-30 minutes. During rinsing it is imperative to open the eyelids as much as possible, directing the water flow into, and around, the whole eye. This is awkward to do, so the injured person may need assistance opening their eyes. Guide him or her to the eye shower; remove any contaminated clothing that might hinder the rinsing. Be firm but calm. If and when your colleague is able to continue rinsing unassisted, help them remove contaminated clothing and rinse other parts of their body that have been exposed to the chemical.

Diphoterine and Hexafluorine

In addition to ordinary eye showers, some labs have installed hand-held chemical showers. These chemicals neutralise the spilled chemical instead of diluting it, as with water. Due to the properties of these chemical showers, there is much less need for rinsing to save an eye or other body parts. There are two types of liquid:

- Diphoterine: This consists of a chemical with both amphoteric and hypertonic properties. This means it can both neutralise OH^- and H^+ ions and it will also "draw out" the chemical, see Figure 15. These properties make diphoterine a good substitute for water when neutralising acids and bases and, to some extent, even oxidisers and solvents.
- Hexafluorine: Consists of a similar chemical as diphoterine, but instead of neutralising OH^- ions it is engineered to accept F^+ ions. This makes hexafluorine a good alternative for neutralising compounds containing fluorine (like HF) as well as being good for neutralising regular acids (but not bases and oxidisers).

Start rinsing as soon as possible and remove clothing and/or contact lenses. Continue washing the uncovered areas as quickly as possible. If you cannot find the neutralising solution, wash with water! It is important to start washing as soon as possible. Do not reuse clothes that have been stained with chemical residues.

Calcium Gluconate Gel

Calcium gluconate gel (HF-gel) is used to treat skin burns from HF. It must always be available and within reach whenever HF is used. If skin is exposed to HF, rinse with plenty of water for a few minutes, or with one bottle of Hexafluorine if available. Dry the exposed area and immediately apply the HF-gel liberally all over the wound, massaging for at least 15 minutes. The HF-gel provides extra calcium ions; these bind to free fluorine ions before they can penetrate your body and cause damage. Repeat the treatment every 15 minutes until reaching medical care.

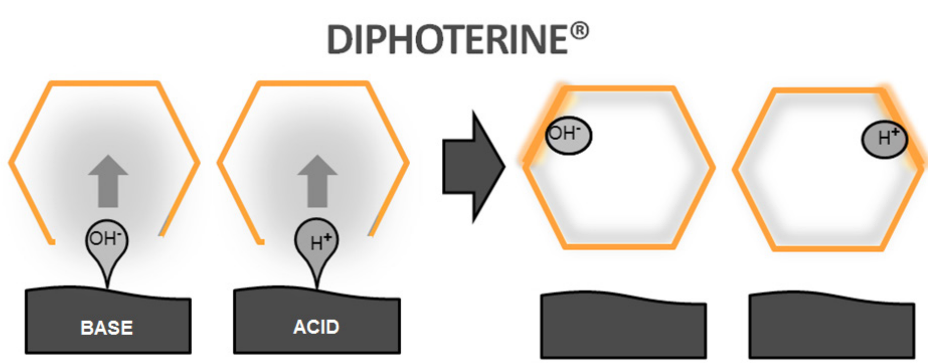


Figure 15: Diphoterine neutralises both acids and alkalis and, to some extent, solvents and oxidisers. Figure taken with approval from Medical Care Systems.

APPENDIX A ELECTRUM LABORATORY

Introduction

Electrum Laboratory and Albanova Nanofabrication Facility are the two laboratories operating within the KTH node of Myfab, the Swedish research infrastructure for micro/nanofabrication. Both these labs present exciting meeting places for students, researchers and entrepreneurs from disciplines as diverse as fundamental science and mature technology. This environment affords you the chance to realise your ideas.

Cleanroom Basics

Kista is home of the Electrum Laboratory with its 1,300 m^2 of cleanroom space and 1,500 m^2 of additional laboratories. This is an outstanding base for fabrication and characterisation on the nano/micro scale. The lab supports the whole chain from education, research and development, to prototyping and production.

At KTH Campus, the Albanova Nanofabrication Facility has a 285 m^2 cleanroom and 60 m^2 of additional laboratories. With focus on direct writing technology, the Albanova Nanolab is a flexible resource for basic research that needs nanofabrication and nanocharacterisation using a wide variety of materials and substrates.

Cleanroom layout

Electrum Laboratory is basically a secluded space within the main building served by a separate ventilation system. Evacuation of the cleanroom in this text means exiting the cleanroom by the nearest emergency exit and reassembling at a specified point.

Figure A1 shows the cleanroom. White areas are clean zones and grey areas are service fingers, in other words areas comprising the back end of installed equipment plus the supply of media to that equipment. These service fingers are not as clean as the clean zones, and the only work normally performed is service work.

Figure A1: Electrum Laboratory cleanroom. The figure shows the current state but due to changes (tool installation/removal) the actual details can look different.

As shown in the figure, the cleanroom is divided into zones. These divisions are not actually visible. However, alarms, ventilation and the distribution of certain gases can be controlled automatically or manually for each separate zone.

Resources

Our resources are available at open access:

- A fully equipped cleanroom with complete, highly qualitative process lines for device research and manufacturing.
- A flexible cleanroom environment for materials and device-orientated research and development.
- World-class characterisation laboratories, providing an integrated in-depth understanding of materials, structures and devices by combining relevant analysis techniques from our palette.
- Sophisticated software for advanced calculations, simulation and design.

You may also rent detached laboratory space for your own specialised tools whilst having access to our full range of services.

Quality Management System

A web-based Quality Management System (QMS) exists with documentation and routines for how the Electrum organization operates. It defines the management structure and it is intended to standardize administrative processes and give users an easy way to find information. It especially describes the quality work (policy, goals, planning etc.). There are also specifications and records of the running of the Electrum Laboratory.

It is also used to make sure that we fulfil the ISO 9001 quality standard and the ISO 140001 environmental standard.

The QMS is accessible from the Electrum LIMS system and from the Myfab portal, with the same user name and password.

ISO 9001 Quality standard

The Electrum laboratory is certified according to the international ISO 9001 quality standard. The standard makes it easier to maintain the quality and improve the consistency the Electrum Laboratory operation.

ISO 14001 Environmental standard

The Electrum laboratory is certified according to the international ISO 14001 environmental standard. Following the standard help us to improve the environment and help us to comply with legal requirements.

5S in Electrum Laboratory

'5S' is the name of a workplace organisation methodology that uses a list of five Japanese words. Transliterated and translated into English, these all start with the letter "s".

The 5S Philosophy focuses on effective workplace organisation and standardised work procedures. 5S simplifies the work environment, reduces waste and non-valuable activity while improving quality, efficiency and safety.

The 5S methodology can be summarised in the following activities:

1. Sort: Sort and remove all material, equipment, papers and so on that are not needed,
2. Stabilise: This means ensuring every item has its dedicated place.
3. Shine: Continuous cleaning and troubleshooting of the work area.
4. Standardise: Standardising means giving people responsibilities for monitoring the 5S activities.
5. Sustain: Resolve identified root causes, make continuous improvements.

Facility Staff

Our highly skilled staff is available for your projects

- Process and development services.
- Commissioned research and development.
- Prototyping and small-scale production.
- Courses in process technology, characterisation and cleanroom infrastructure.

Improvement Groups

Every room in the Electrum Laboratory has an "improvement group" including the person responsible for the room and the room's most frequent users. Improvement groups are responsible for the 5S activities in their respective rooms. Improvement groups hold regular meetings in which ideas are discussed, decided upon, documented and implemented. Standardised binders and documents are available to aid every 5S improvement group. The 5S activities are an everyday part of the work performed in the Electrum Laboratory.

Regular revisions of the different improvement groups are conducted so that the progress of 5S in the laboratory can be monitored. These revisions follow a standardised protocol that objectively measures and gives feedback of the current status and progress made by the group.

Working Environment and Safety

Working Hours

Normal working hours are Monday to Friday 07.00-18.00. Work should always be planned so that only exceptionally does it take place outside normal working hours. Working alone in cleanrooms is strictly prohibited. At least one colleague must be present.

Safety Arrangements

Electrum Laboratory is responsible for the general safety of its laboratory and coordinates safety work and measures between its users. This is done by the safety group, comprising members from the user groups and Electrum Laboratory itself.

Specifically, this means managing such issues as:

- Safety infrastructure: Eye showers, hydrogen and toxic gas monitoring plus other parts of the alarm system, exhaust air and so on.
- Safety arrangements: Organising an alarm group, on duty outside of normal working hours.
- Authorisation contacts: Managing necessary permits for the possession and use of certain chemicals and gases. Keeping track of legislative updates relating to laboratory activity and implementing them as necessary.
- Review of the laboratory environment from a safety perspective, at least once every 12 months.

Faults and discrepancies regarding laboratory operations should always be reported to Electrum Laboratory.

Alarm Group

Electrum Laboratory organises an alarm group, consisting of Electrum Laboratory staff and experienced lab users; some 8-10 people with a fair knowledge and understanding of the cleanroom. The alarm group's tasks are:

- assembly at the alarm centre in case of an alarm,
- investigating the reason for the alarm,
- preparing equipment and protective gear for this purpose,
- searching for any injured personnel inside the cleanroom (using protective gear if necessary), once the reason for the alarm has been established,
- finding, evacuating and attending to any injured personnel,
- notifying the emergency services if necessary,
- attending to the cause of the alarm,
- supporting the emergency services once they arrive.

Electrum Laboratory does not expect all 8-10 members of the alarm group to be present in, or just outside, the cleanroom at any given time. The idea is that with that many members, at least four or five should be present during normal working hours and able to implement alarm group tasks as needed.

On Duty

During normal working hours, there are always enough people from the lab's alarm group available to deal with an incident. Outside normal working hours, Electrum Laboratory has a person on call at home. This person will always answer the telephone at the on duty number (above) and will, if necessary, arrive at the Laboratory within 45 minutes (usually within 20-30 minutes) of an alarm or telephone call. Outside normal working hours, the consequences of an accident may be much more serious than during them. Primarily, this is because only a few people are present, however it also takes time for the on duty person to get from their home to the laboratory.

Those who work in the laboratory outside normal working hours should:

- work with a colleague who will be ready to help in case of an accident,
- notify the Electrum group and the alarm group. This must be made by email to elab-techsupport@ict.kth.se (combined elab-center@ict.kth.se and QLA@acreo.se) – before 13.00 the same day,
- for weekend work the Electrum group and the alarm group, elab-techsupport@ict.kth.se, must be informed no later than Friday, 13.00.

NB this registration must always be submitted for work conducted outside of normal working hours.

Outside of normal working hours you may only carry out operations and processes which are well known and described in manuals and recipes. For potentially dangerous work there must always be two people present in the same room and both well-versed in the process. These include:

- handling acids, bases and warm solvents,
- processes using corrosive, toxic and/or flammable gases.

It is forbidden, for any reason whatsoever, to perform potentially dangerous servicing work:

- on equipment for handling corrosive, toxic and/or flammable chemicals or gases,
- changing of gas bottles or corrosive, toxic and/or sources of ignition.

Red lights outside the entrance locks indicate that the cleanroom is closed.

The card readers will still allow you to open the doors, but you should always bear in mind the risk of contaminating a cleanroom by opening a door.

Chemicals may remain in the acid/solvent baths during night, but all bath lids and fume hood doors should be closed, as they should always be if the bench or fume hood is not in use.

Cleanroom Rules

Please obey the recommended proper cleanroom practices as described in the Myfab general manual.

When entering a cleanroom, users should wear cleanroom coveralls, hood with face mask, cleanroom shoes and disposable gloves, see figure A2. For more info, please see document: acr 024688-Instruction for entering and leaving the cleanroom.

Violation of safety rules or irresponsible conduct may result in disciplinary actions. The Laboratory Director has the right to adjudicate these cases. The penalty for lesser violations will be a warning, but more serious offences will result in suspension. See also the routine for Disciplinary Action for Misconduct, laboratories, ICT-school.

Costs and Charges

At Electrum, the costs are distributed between the various laboratory groups. This covers all general costs for maintenance of the infrastructure at Electrum Laboratory and includes personnel, rent, electricity, cooling and heating, media including house gases, wet chemicals for general use, some depreciation and so on. All costs associated with the tools in the laboratory are defrayed by the responsible user group, including spares, service and maintenance, consumables, such as tool-specific gases and chemicals and, in some cases, depreciation related to those tools.

This also means that the charges must be distributed between the various groups. Hence, Electrum Laboratory charges its users in three ways:

- A monthly fee for all registered users (applicable for the full period for which the cleanroom access card is activated).
- Hourly fees for time spent in the cleanroom (based on card reader registration).
- An area fee for all tools in the cleanroom (the responsible group is charged).

Figure A2: Image of user gowning for Electrum Laboratory.

The responsible groups then charge lab users for their tool usage, according to what is recorded in the logbooks in LIMS. Usage fees follow the Tool Rates laid down by Myfab, and are shown in Myfab LIMS. It is of the utmost importance that all lab usage is logged and presented properly so that costs are distributed fairly.

Rules for Tool Booking

1. Myfab LIMS is used for booking and logging laboratory tool usage.
2. All tools marked "Booking: compulsory" on the tool label or "Booking type: Compulsory" in LIMS must be booked before use.
3. You must create a log in LIMS every time you use any tool marked "Logging: Compulsory" on the tool label or "Log level: Compulsory" in LIMS and for every booking you make.
4. To make it easier for all users to get access, you may book no more than 8 hours per day, or two consecutive days on the same tool. This rule does not apply to tools with very long process times (such as furnaces).
5. Exceptions to rule no. 4 may only be made during those periods when the tool is not fully booked by other users. In this case, you may book more time on the same day you want to use the tool.
6. The responsible person may lay down special rules for booking/logging. For example, minimum or maximum times allowed/recommended for booking/logging.
7. If you cannot use the tool as planned due to a major miscalculation of the time needed for a process, or due to other problems, you must cancel the booking. Please note that only future bookings can be cancelled by users.
8. If it is too late to cancel the booking, you should reduce the time booked as much as possible and contact the relevant responsible person to explain the situation and get help with logging.
9. You may use up tool time that was booked by another user if that tool is still free within half hour of the beginning of your booking period. However, the "booking owner" should be contacted before you begin using the tool. In this case, you should log your use without booking, by using the Log status page.

10. Charging for tool usage is based on the time logged.
11. The usage time that you log should not be shorter than the time booked. Only when rule no. 8 applies may you report a shorter time than was booked.
12. If rule no. 11 is not observed, you may be charged for equipment usage according to your booking.
13. For runs shorter than full hour(s), the usage time will be rounded up.

Chemicals

All chemicals must be approved for use by the Lab Director and should be registered in the Myfab LIMS system and KLARA system. Such chemicals must be registered with an SDS. Standard chemicals, for use by multiple laboratory groups, will be supplied by the Electrum Laboratory. Other chemicals may be used after approval, but ordering and costs must be covered by the group needing them. For more information, see the Electrum quality manual.

Handling Chemical Waste

General rules:

- After use, all chemicals are to be treated as hazardous waste.
- If in doubt, seek advice from experienced personnel and contact Electrum Laboratory personnel before processing.
- “Standard” acids and bases may be emptied into the acid drain (HCl, H^2SO^4, HNO^3, HF, KOH, H^2O^2, H^3PO^3, NH^3, acetic acid and the like).
- “Standard” organic solvents may be emptied into the solvent drain. Avoid discharging n-methyl-2-pyrrolidon (aka NMP or Remover 1165) into the solvent drain. Collect this waste in plastic bottles and dispose of as a common waste product (see below).
- No chemicals may be emptied into the communal/external drain or disposed of with the paper waste. Empty bottles are to be rinsed thoroughly (check with pH/litmus paper as necessary) and disposed of in the container for hard plastic, without the cork/cap screwed on.

Failure to follow this procedure can damage waste disposal equipment or cause personal injury.

All other waste products are to be sent for destruction.

- Use plastic bottles to collect waste. Avoid glass bottles if at all possible.
- Ensure that packaging is clear of spills and enclosed in a plastic bag. Clearly mark the packaging with its contents plus your own name and department.
- Common waste products known to users and Electrum Laboratory must be placed on the bottom shelf of the pass-through. Indicate on the whiteboard of the outer room that this waste is to be collected. Common waste products means those that accumulate and are disposed of on a regular basis (every few weeks) such as photoresist, gold etch, NMP, GaAs contaminated waste and polishing slurry.
- All other waste must be packaged and labelled as above and the Electrum Laboratory staff contacted for its immediate removal from the lab. Unusual or high-risk waste must be transported directly to the hazardous waste storage area and must not be allowed to accumulate in the lab.

Under no circumstances must this type of waste be left on the floor or in cupboards for collection in the general disposal process.

Alarms and Emergencies

The Electrum Laboratory alarm system is a collection of monitoring subsystems in the building, including a system for forwarding alarms by SMS. These alarms are displayed on a chart at the alarm centre.

Alarms and Evacuation

The cleanroom is fitted with a network of manually activated fire alarms in case of accident. Red coloured manual fire alarm buttons are located inside the laboratory, if a user discovers a fire but the alarm has not yet

Alarm Type	Reason of the Alarm	What to do
Blue flashing light	Technical fault.	Contact service personal. Other users can continue to work if they are not effected by the alarm.
Yellow flashing light, continuous siren. Only visible in the effected zone.	Low concentration of hydrogen has been detected, or that the alarm has been manually triggered by pushing one of the yellow buttons inside the cleanroom. At high concentrations of hydrogen the supply of hydrogen to that zone shuts down. If the alarm is not reset to normal conditions within 10 minutes, the hydrogen lines will automatically be flushed with nitrogen.	Only personnel working in the affected zone must evacuate that zone.
Yellow-Blue flashing light and continuous siren. Only visible in the effected zone.	Evacuation of the zone is triggered by low concentration of toxic gas in the monitored cleanroom zone or high concentration in the exhaust.	Only personnel working in the affected zone must evacuate that zone.
Red flashing light, oscillating siren	Triggered by the fire alarm, high concentration of hydrogen, high concentration of one of the other gases monitored by the toxic gas room sensors, or manually by pushing one of the red buttons in the central cleanroom corridor. The supply of hydrogen and oxygen to the cleanroom shuts down. If the alarm is not reset to normal conditions within 10 minutes, the hydrogen lines will automatically be flushed with nitrogen.	Total Evacuation, go to assembly point. The alarm system will stop the air supply and circulation, leaving the exhaust on, which creates an under pressure in the cleanroom, which makes the door difficult to open. This prevents any toxic gases to escape out into the main building, and also limit the supply of air to any fire.

Table A1: Possible reasons for an alarm and instructions on what to do.

activated. There are also yellow alarm buttons which manually trigger certain alarms, either when there is urgent need to evacuate a particular zone, or when assistance from the alarm group is needed urgently. The various alarm types are shown in the following table:

Fire Extinguishers

If a fire incident can be controlled and put out by a lab user early on and without any form of risk-taking, then this action is acceptable. However, any form of risk-taking, calculated or otherwise, is absolutely forbidden. Any incidents of this nature should be handles by the alarm group.

Evacuation

An evacuation alarm should be met with immediate action by lab users:

- Leave the cleanroom without hesitation and go to the nearest emergency exit. Emergency exits are marked with green and white signs as per international standards. All clean zones have emergency exits in the actual room where work is carried out. Almost all the service fingers have emergency exits. There is at least one alternative exit from all locations in the cleanroom.
- Go to your assembly point and await further instructions. Do not leave the assembly point unless the alarm group authorises this action.

The indoor assembly point is near the stairs to the cafeteria, see figure A3. If you need to exit the building, the outdoor assembly point is outside Isafjordsgatan 26, see figure A4.When evacuating, do not waste time removing your cleanroom clothing; leave it on. Do not delay evacuation by trying to complete work that otherwise might be spoiled.

During evacuation, be sure that your colleagues follow your example. Help them if necessary and possible. If possible, account for the whereabouts of colleagues who appear to be missing.

Some equipment and processes in Electrum Laboratory calls for certain actions by the operator in the event of an evacuation alarm. Those actions are machine and process-specific and will not be described here.

Electrum Contact Information

Electrum address:	KTH, Royal Institute of Technology Electrumlaboratoriet Isafjordsgatan 22-24 164 40 Kista
Important tel.nr:	Electrum laboratory emergency/on duty nr - 070-648 60 32 St Erik eye clinic 08-672 31 00

Quality Manual

http://www.myfab.se/KTHAcreo/UserInformation/ElectrumQualityManual/

Figure A3: Indoor assembly point, below cafeteria.

Figure A4: Outdoor assembly point, Isafjordsgatan 26.

APPENDIX B LUND NANO LAB

Introduction

The Lund Nano Lab (LNL) of the Division of Solid State Physics, Lund University, is an open-access resource within NanoLund Consortium at Lund University. The laboratory is accessible to all academic researchers and corporate users. LNL provides access to and expertise in MOVPE, aerosol technology and aerotaxy, ALD, nanoimprint lithography and other methods of micro/nanofabrication. The lab staff are responsible for cleanroom and safety training of new lab users and will provide technical support for lab customers. All LNL users must attend a safety update course (given 4 times/year) at least once a year in order to keep the access to the lab.

Cleanroom Basics

LNL includes three cleanroom areas on two levels: (1) Nano-process lab ("white area", level 1), (2) Nano-epitaxy lab ("blue area", level 2) and (3) Berzelius lab ("green area", level 2). The Nano-process and Nano-epitaxy labs were built in 2007, while the older Berzelius lab was constructed in 1984. Each cleanroom area has its own entrance (white, blue and green) and different gowning procedures. Gowning procedures are detailed in the Rules and Work Instructions section of the appendix. Figures B1 and B2 show schematics of the LNL cleanroom, Level 1 and Level 2 respectively:

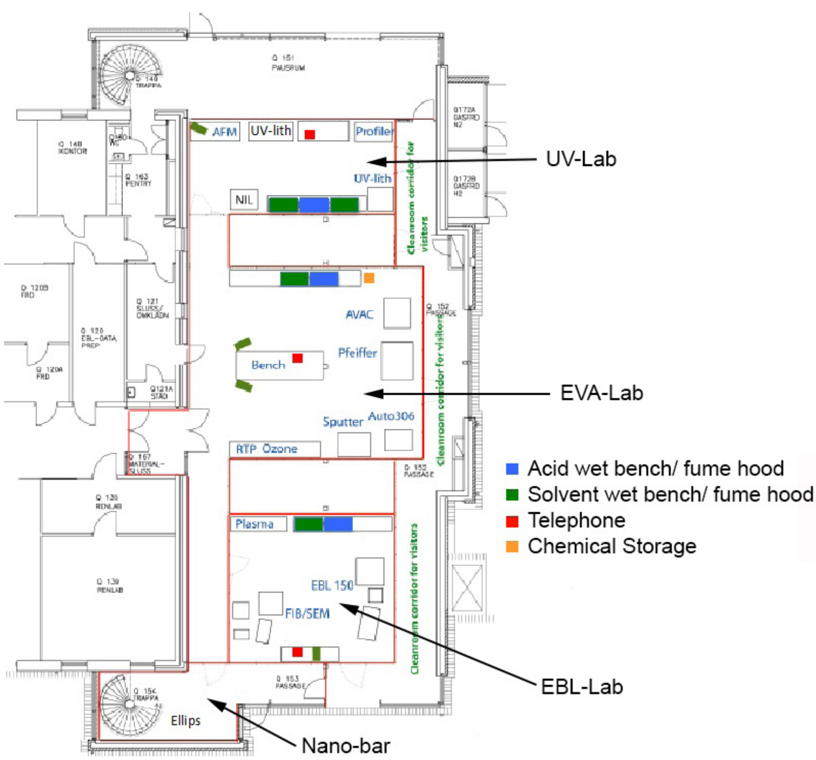


Figure B1: Nano-process lab, white area (Level 1).

Rules and Work Instructions

Entering Cleanrooms

Depending on where the main work is being carried out, you may enter the LNL cleanrooms via level 1, white-marked area, or via level 2, blue/green marked area, using the corresponding cleanroom garments. To minimise contamination in the Nano-process lab, movement between the levels is restricted:

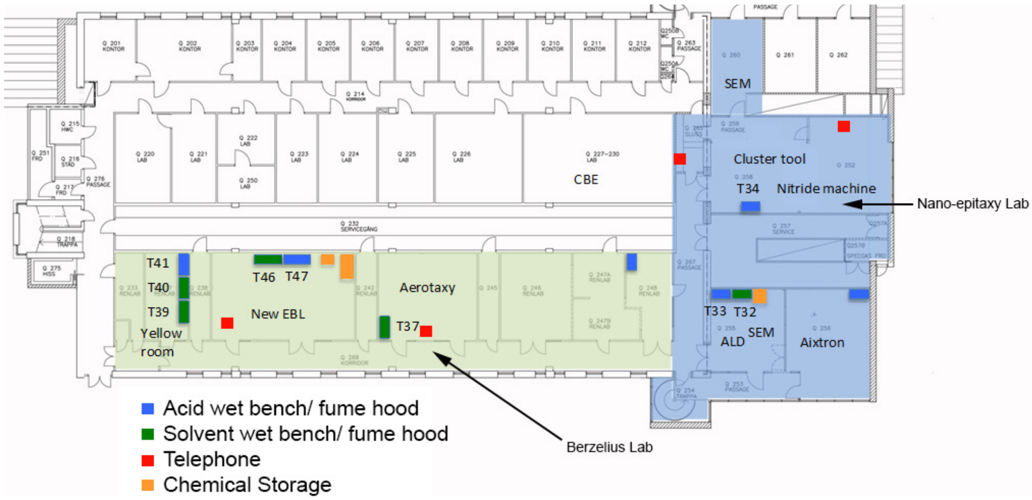


Figure B2: Nano-epitaxy, blue area and Berzelius lab, green area (Level 2).

- Lab users dressed in white coveralls may go to the "blue area" only; entrance to the "green" part of the lab is forbidden. The duration of such visits should be limited (10-15 minutes), no regular work should be performed in white coveralls in the "blue" area, but it is acceptable to do time-limited work such as loading/unloading samples or similar activities.
- People dressed in blue or green coats may visit the "Nano-bar" room (ISO 7) on level 1, but not inside the ISO 5 area of the Nano-process laboratory (except in case of emergency).

Gowning Procedure

There are different gowning procedures for different levels of LNL. On level 1 (Nano-process lab, class ISO 5): users should wear white coveralls, hood, booties and disposable gloves. On level 2 (Nano-epitaxy lab, the "blue area", class ISO 7), users should wear blue lab coats, hairnet, disposible gloves and lab shoes (booties covering ordinary footwear are also acceptable). In the Berzelius lab or "Green area" (on level 2, class ISO 8) users wear green lab coats, hairnet, disposable gloves and lab shoes (or booties to cover ordinary shoes). Figure B3 illustrates the different garments needed for the Nano-process lab, Nano-epitaxy lab and Berzelius lab, going left to right.

Before Entering the Changing Area

Remove any outdoor clothing or other extraneous garments (such as pullovers or jackets) outside the lab. Watches and rings may be placed in small lockers (changing room, level 1). Mobile phones are NOT allowed in the Nano-process lab, level 1. On level 2 (Nano-epi and Berzelius labs), it is permissible to take phones once they have been cleaned. It is recommended to visit a restroom before entering the cleanroom. Please note: you must remove any cosmetics since these are regarded as contaminants.

Exiting the Cleanroom

To exit the cleanroom, use the following procedure to remove your cleanroom garments:

- For level 1: remove booties and put them on a shelf. Take off your hood and coveralls and hang them on the hanger without allowing any part of them to touch the floor. Remove and dispose of your gloves. Collect your personal belongings from your locker. As you are leaving the changing room, dispose of your hairnet.
- For level 2: remove cleanroom shoes and put them on a shelf. Take off your coat and hang it on the hanger. Remove and dispose of your gloves. As you are leaving the changing room, dispose of your hairnet and booties.

Working Hours and Lab Buddies

The lab is open 24/7/365 except for certain holidays. When closed, notifications will be sent via LIMS to all registered users. The lab staff is typically present between 8.00 and 17.00 on weekdays. To get the full support of the staff and for safety reasons, lab users should only use the labs during the normal working hours. If you are working late (after 19.00 or any time during weekends and holidays), a lab buddy must be present.

Figure B3: Cleanroom apparel, from left to right, for Nano-process lab, white area (Level 1), Nano-epitaxy lab, blue area and Berzelius lab, green area (Level 2)

When Work in LNL is Completed

It is the responsibility of each user to inform the Lab Operations Manager when their work in LNL is finished. Your LIMS account and LU lab access card will be deleted.

Chemicals

Working with Chemicals

Safe work with chemicals requires special training, which includes:

- studying SDSs of chemicals,
- writing Risk Assessment Forms (RAF) for any new chemical process,
- practical training in how to use wet benches and fume hoods.

Maps indicating the positions of wet benches and fume hoods appear in Figures B1 and B2. In total, there are seven wet benches and fume hoods in the cleanroom areas. There are four wet benches which can be used for HF-based solutions, two of which are located on level 1 (EVA lab and EBL lab). The other two are located on level 2 (ALD lab and New EBL lab).

Protective Equipment

All users who work with chemicals must use protective equipment, which includes aprons, goggles, chemical gloves, sleeves and face shields. Using face shields is compulsory when using chemicals. Figure B4 demonstrates the user's protective gowning in the Nano-process laboratory.

Handling Chemical Waste

Collect solid waste in dedicated boxes separate from the solvents, bases and acids which are also collected in their own dedicated bottles. Items contaminated with resists or solvents must be placed in dedicated bins. Do not mix organic and inorganic chemicals. There is a solvent drain system on level 1 which is equipped with a level meter. When the red LED starts blinking DO NOT pour in more solvent waste; contact lab personnel. When using dedicated bottles to collect waste, do not fill the bottles to the top; leave sufficient space for any gas produced. Make sure waste bottles are correctly marked. It is absolutely forbidden to pour any chemical into the sink.

Figure B4: Full chemical protection: face shield, chemical gloves, apron, and sleeves.

Chemical Spillage

The spillage of chemicals in the cleanroom is an emergency and constitutes a serious accident because chemical vapours will spread through the internal lab ventilation. Lab staff must be informed immediately in case of a chemical spillage. Follow the instructions given by lab staff. A small spillage can easily be handled by lab users. Any work to remove a spillage must be carried out with extreme caution, using all available protection (chemical gloves, apron, face shield and sleeves).

In the case of a larger chemical spillage, inform all users present in the lab (all rooms on the same floor) that they must leave the lab calmly via the changing room. Leave the lab yourself. Contact lab staff to report the spillage; they will then take over. Remain in the vicinity to answer any questions the lab staff might have regarding the spillage. If nobody from the lab staff is readily available, contact emergency service by calling 0-112 (112 from any mobile phone) and inform them of:

- the chemical,
- the amount of liquid spilled,
- any lab users affected by the spillage.

The lab will be reopened when it is safe again. In case of personnel being exposed to chemicals, contact emergency service immediately and give the following address for the ambulance: Professorsgatan 3, 223 63, Lund.

Alarms and Emergency

Emergency Procedures

In the case of an evacuation alarm (bells and sirens), evacuate the cleanroom at once. Leave the lab immediately via the nearest emergency exit; there is no time for changing clothes. Check that no one is left behind; if so, help them evacuate without risking your own life. Remember to check the evacuation routines. Identify your assembly point and go directly to it, see figure B5.

There are two types of alarms in the Lund Nano Lab:

- Visual (the alarm lamp stations) installed in the cleanroom show the status of Lund Nano Lab, such as ventilation, power and so on.
- Audible (bells and sirens) activated in case smoke, fire or process gas detection. Local audible alarms (buzzers) can be activated due to an equipment malfunction, such as insufficient ventilation through wet benches.

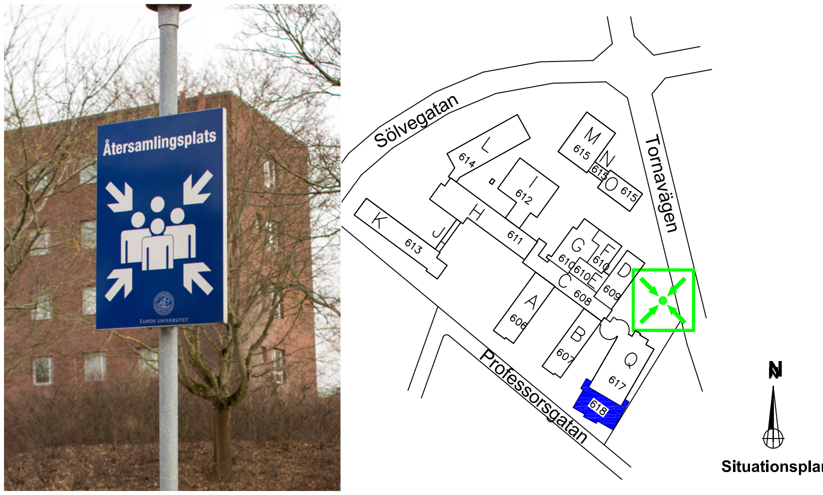


Figure B5: Outdoor assembly point sign and schematic of the area.

Audible alarms (bells and sirens) mean that you must evacuate the lab immediately. You should activate the alarm manually (open cover or break the glass) if the automatic fire/gas safety system does not work.

Table B1 shows information specific to LNL regarding what to do in case of an alarm. Please note the relevant contact telephone numbers are available by the phones in the lab.

Alarm Type	Reason of the Alarm	What to do
Blue	Power failure.	Leave the lab. Contact LNL safety personnel, Operations Lab Manager or their deputy.
Yellow	Process ventilation malfunction (wet benches will make a continuous alarm sound).	Not safe to work with chemicals. Switch off hot plates or other equipment on wet benches, leave the lab. Contact LNL safety personal, Operations Lab Manager or its Deputy
Orange	Process gas cabinet ventilation malfunction.	Contact LNL safety personal, Operations Lab Manager or its Deputy. Be prepared to leave the lab.
Red + local sound from lamp post	Process gas detected, low concentration.	Switch active equipment to a safe state. Contact LNL safety personal, Operations Lab Manager or its Deputy. Go to corridor Q267, check gas detection system. Be prepared to leave the lab.
Red + bell or siren sound (Evacuation)	Smoke, fire, manual alarm activation and/or high concentration of process gas	DANGER! Leave the lab immediately! No time to change clothes!

Table B1: Possible reasons for an alarm and instructions on what to do.

LNL Contact Information

LNL address: Lund University
Physics Department, Division of Solid State Physics
Professorsgatan 1
223 63 Lund

Telephone numbers to lab areas:

UVL-lab, Q161, Nano-process: (046-22)23980
EVA-lab, Q158, Nano-process: 23981
EBL-lab, Q156, Nano-process: 23982
Aerotaxy lab, Q243-244, Berzelius: 23985
New EBL-lab, Q239-241, Berzelius: 23986
Nano-epi, Level 2 (corridor): 27663
Epi Room, Q258: 23983

APPENDIX C MC2 NANOFABRICATION LABORATORY

Introduction

The Nanofabrication Laboratory (NFL) at the Department of Microtechnology and Nanoscience, Chalmers University of Technology, offers a broad platform for conducting advanced processing in micro and nano technologies. The laboratory is run as an open infrastructure for academic and commercial interests and offers access on equal terms to all users of the same category. The laboratory is run by a staff equivalent to 20 full-time employees from various backgrounds in academia and industry and with an average of 20 years' cleanroom experience.

Cleanroom Basics

The laboratory is divided into areas with different cleanroom classes (including lockers and gowning area) as follows: Process Laboratory 1 (PL1), see figure C1, Process Laboratory 2 (PL2), MBE Lab, Dicing/CMP room and Chemical Handling Room.

The PL1 is ISO 5 class and has all equipment relevant to handling processes for such things as microwave, terahertz and photonics device processing, nanostructuring, MEMS, microfluidics and bolometers. The total area is approximately 1,000 m^2. Temperature and relative humidity are well-defined, residing between 19±0.1°C and 43±3% RH, respectively. The air-handling system has a maximum capacity of approx. 500,000 m^3/h. The air entering PL1 passes through some 500 HEPA filters, covering approximately 25% of the total ceiling area. The vibration specifications are within the BBN-E class.

Figure C1: Distribution of equipment in the PL1 cleanroom.

PL2 is a cleanroom of ISO 6 class and includes specials areas for deposition of High Tc superconductors, functional oxides, ferroelectrics and Graphene/CNT using laser ablation (PLD), sputtering and CVD. The total area of PL 2 is approximately 240 m^2.

The MBE room is for production of III-V materials, the CMP room is for preparation, dicing, and polishing of semiconductor devices and materials and the Chemicals Handling Room is for preparation and limited storage of special chemicals for the cleanroom.

The laboratory hires specially trained personnel to clean the laboratories and other areas within the facility. Although the people within this group are not formally members of the lab group, they are nevertheless an integral part of the lab. As a user, you will meet them every now and then as they work, but if you need support please refer to the lab staff (dressed in green cleanroom garments).

Outside the cleanroom on floor 3, are two laboratories for XRD and PPMS. In the basement on floor 1, there is a tap station for LN2.

Rules and Work instructions

Cleanroom Access

New users are only allowed access during office hours. Extended access is only given to experienced users and is only granted upon request. For safety reasons, we urge all users to initially plan their activities during office hours. After their cleanroom course, each user must sign to confirm their awareness of cleanroom regulations and complete a questionnaire about cleanroom safety and practices.

Entrance is through the main entrance, D section, level 3 (D3) in the MC2 building outside PL1, or at section A, level 2 (A2) outside PL2. Entrance into PL1 is only allowed through the main entrance at D3, while other areas may be accessed through A2 (special approval required). To simplify the logistics of cleanroom garments, the general rule is that you should exit from where you entered. All other doors are locked and alarmed to ensure a properly protected internal shell.

Cleanroom garment

For PL1, the standard dressing procedure is as described in section 4.2.2. Regular users wear white apparel and Lab staff are dressed in blue. In the other lab areas, lab users and lab staff wear the same apparel.

Figure C2: Different cleanroom apparel depending on user and lab area. Left: PL1 garment for lab staff. Centre: PL1 garment for lab users. Right: Garment for staff and users in other areas.

Working Hours

The lab is open 24/7/365, except on certain holidays such as Christmas and New Year. All lab closures are announced in our newsletter and/or in Myfab LIMS about a month in advance, or with as much notice as is possible. Office hours are limited to weekdays between 07.30 - 18.00. People from the lab staff group are normally available during these hours. A lab buddy is required at all other times.

Materials Storage Options

Users may store processed materials and personal items inside or in close proximity to the cleanroom. There are three common storage locations inside the lab: wire-rack shelves for personal toolboxes, yellow N_2 purged storage boxes in lithography areas and a few cabinets dedicated for materials storage in which different user groups may have their own space.

These boxes are intended for temporary storage of processed materials and personal items such as tweezers, cleanroom pens and notebooks etc. The main reason for this is to limit the number of items and materials on work surfaces in the laboratory. It is the responsibility of each user to ensure that these surfaces are not used as long-term storage. Unlabelled items lying around for any length of time will be removed by lab staff and will eventually be disposed of. Only inert materials may be stored in personal tool boxes.

Facility Staff Responsibilities

The lab staff at MC2 has functions and responsibilities such as:

- To give advice and suggestions regarding process issues.
- To support users with process development and fabrication.
- To ensure that safety and equipment standards are maintained.
- To carry out servicing and maintenance.

It is NOT the responsibility of lab staff to clean equipment and wet bench areas after users.

Costs and Charges

All users are charged according to their use of the facility. Costs for standard consumables (chemicals, wafers, wipers and the like) acquired by the process lab are included in our charges and need not be accounted for by users. However, special items such as special wafers or expensive materials will be charged based on consumption.

Please note that lab staff cannot guarantee the outcome of a project. Charging is implemented regardless of whether the project was successful or not, or whether the expected yield could be achieved or not. Lab staff accept no responsibility for delays or unexpected cost increases related to the project.

Work environment and Safety

Protective Gear

All users at MC2 are expected to wear safety goggles at all times when working in any of the cleanroom areas. All users who work with hazardous chemicals must wear full protective gear, which includes aprons, goggles, chemical gloves, sleeves and face shields. For a complete chemical safety gear, see figure C3.

Handling Chemical Waste

There are two drainage systems installed in the labs; solvent drains and acid drains. It is extremely important that you use the correct drainage system for your used chemicals, since mixing of incompatible chemicals could cause an explosion in the waste-handling facility.

The acid drain should be used for standard acids and bases. This waste is passing through a neutralisation tank which ensures that water released into the public drainage system is always neutral, with a pH of 7.0.

Users who intend using large quantities of chemicals are requested to contact lab personnel, who will ensure that there are sufficient quantities on hand in the lab. If a chemical is used up, please contact the lab personnel. After training and instruction by lab personnel, any non-standard chemicals or mixtures should be prepared in the Chemical Preparation Room.

Ventilated Work Areas

A large number of process benches are installed in PL1, PL2, CMP/Dicing, and in the Chemical Preparation Room. These benches have built-in functions for etching, spin-coating/developing, wafer cleaning and so on. When you are about to start working at a process bench, you will see a status signal light mounted on the bench, showing continuous blue. This indicates that the bench is currently only using 10% of its nominal exhaust capacity. To increase the bench exhaust flow to its nominal value, push the exhaust button. If there is enough capacity in the total exhaust system at this moment, a valve will open to enable nominal exhaust flow for this bench. At the same time, the status light will change from continuous blue to continuous green. If the green light does not light up, too many benches are already in use and you will have to wait until a bench is turned off.

For safety reasons, you are only permitted to use a process bench when the continuous green light is on, i.e. when the exhaust flow is sufficient. To avoid accidents, never allow more than one person/chemical setup per bench.

Figure C3: First two pictures showing the hangers for protective gear; gloves, face shield, apron and arm cover. Fully equipped chemical protection seen to the right.

As soon as you have finished your work at the process bench, you should press the exhaust button again. This means the exhaust flow for the bench will return to 10% of its nominal value and that the electricity to the installed equipment such as hotplates, heating baths and so on will be turned off. Failure to turn the bench off may block the availability of benches to other users. Once your bench has been on for a certain time (normally four hours), you will hear/see a warning signal. At this point, you must press the button twice to quickly turn the bench off and on to continue working. If not turned off manually, the bench will eventually shut down automatically and the status light will change to flashing blue. The bench is now disabled and must be restarted.

Alarms and Emergency

Alarms and Evacuation

To reduce the risk of hazardous gases, MC2 employs an advanced system for detecting dangerous gas leaks. This system is supervised and maintained by the maintenance staff, according to a strict procedure. The gas detection alarm and general fire alarm are indicated by a flashing red light plus an audible signal.

In addition to the fire and gas-detection alarms, a ‘process alarm’ is installed. This detects conditions which are not dangerous to humans, but which post immediate danger to a product, equipment or the facility. This process alarm is indicated by a blue flashing light combined with three short, audible signals.

Alarm Type	Reason of the Alarm	What to do
Blue flashing light and three short acoustic signals at start of alarm	Process/service failure.	Find more information on the screen close to the exits. Quickly finish your process if it includes water or gases. Contact lab staff if necessary. Evacuation is normally not necessary.
Red flashing light and acoustic signal (gas alarm)	Leakage of hazardous gases within the lab	Evacuate the lab immediately. If there is no signal outside the lab it is acceptable to stay/enter in the office area in the building.
Red flashing light and acoustic signal (fire alarm)	Smoke, fire, manual alarm activation and/or high concentration of process gas	DANGER! Evacuate the building immediately! No time to change clothes! The acoustic signal may be silence, but don’t re-enter the premises until the flashing light disappear.

Table C1: Possible reasons for an alarm and instructions on what to do.

In the event of a fire or gas alarm, the cleanroom should be evacuated immediately in a manner described in the relevant evacuation plan. Leave the lab through the nearest emergency exit. Do not take off cleanroom garments before exiting the building; these can be washed later.

The internal public address loudspeaker system can be accessed outside PL1 and PL2. This system is an important part of the overall safety function, as users can be quickly informed of risks and other important matters.

Chemical safety accidents

Folders with SDS for standard chemicals is available within the laboratory. This folder should be brought to the ambulance personnel if there is a chemical accident.

Fire extinguisher

Only qualified labb staff and rescue service are allowed to use the fire extinguisher in the MC2 cleanroom areas.

MC2 Contact Information

Telephones
The cleanroom has a few telephones available for outgoing calls. During the daytime, lab staff may be called any time if there is problem with the facility or process-related issue. At night, Chalmersfastigheter may be contacted regarding any issues relating to the facility, but problems related to processing must wait until office hours. A list of all the lab staff telephone numbers may be found near the telephones, inside the labs.

MC2 address:	Chalmers University of Technology Microtechnology and Nanoscience - MC2 Kemivägen 9 412 96 Göteborg
Important tel no:	Chalmersfastigheter AB – 031 7724937

APPENDIX D ÅNGSTRÖM MICROSTRUCTURE LABORATORY

Introduction

The new cleanroom, with shared equipment for materials research, was the single most important reason for Uppsala University to establish the Ångström Laboratory during the 1990s. It has been operated as an open user facility from the start; a model which has been further developed and fortified by the involvement with Myfab. The Ångström Microstructure Laboratory (MSL) is a versatile toolbox for materials science with special emphasis on micro/ nanotechnology.

Cleanroom Basics

The Ångström Laboratory cleanroom is divided into two main sections with differing cleanliness and gowning procedures. The largest part is the classified section, with lab areas ranging from ISO 7 (class 10,000) to ISO 5 (class 100). Everyone entering this area must wear overalls, cleanroom shoes and gloves. The non-classified section (about 1/3 of the total area), where lab coat and cleanroom shoes are sufficient, maintains a particle level corresponding to ISO 8 (class 100,000). This is about one order of magnitude lower than in a normal office. Most of the processing tools are in the classified section, whilst all analysis tools are found in the non-classified section.

Figure D1: Cleanroom layout with separate classified and non-classified sections, vibration-free area and location of some important instruments (not exhaustive).

The temperature is set at 20 °C in the classified section and 21 °C in the non-classified section (where long stationary sessions on various analysis tools are common). In both cases, the temperature is controlled to within ±1 °C. Humidity should not exceed 65 % RH anywhere and is kept to 43 ±5 % RH in the most well-controlled areas (such as lithography and ISO 5).

Independent foundations support a "vibration-free" area in the cleanroom (fulfilling requirements for class BBN-E). This extends into both sections, providing the right conditions for such activities as lithography and electron microscopy.

Specially trained personnel are assigned to clean the cleanroom. They have a very important mission and try to do an excellent job, but can only do so if everybody else contributes by keeping surfaces clear and removing all objects that are not being used.

Administrative Guidelines

Laboratory Access

Preliminary (interim) lab access can be obtained once the following three steps have been carried out:

- Approval from an acknowledged supervisor/project leader (brief e-mail to lab management).
- Submission of an electronic access application (http://lims.msl.angstrom.uu.se).
- Participation in on-site introduction (pre-scheduled with MSL staff once the first two steps are complete).

This will give access to all areas except lithography and wet chemistry. With regular lab access, a user may then apply for tool training to gain operator licence(s) and booking privileges to tools of interest.

An introductory seminar (held approximately once a month) must be attended for permanent lab access to be granted. The interim access will be revoked if the user has not taken this seminar within two months of activation (without presenting an acceptable explanation to the MSL management).

A separate chemical safety seminar (normally held the same day as the introduction for new users) is required for access to lithography and wet chemistry. Users with this level of access are charged a higher access fee (to cover the cost of chemicals and other consumables) and approval from a supervisor/project leader is therefore mandatory.

Most consumables are covered by the access fee, but some expensive material such as wafers, lithography masks and noble metals are charged based upon consumption.

Before starting an individual project, a new user is recommended to have a start-up meeting with his/her supervisor and an appropriate MSL staff member to ensure their project plan is compatible with lab resources. This is particularly important for users planning to run process sequences and for users unconnected with any established user group.

Individual user access remains in force until actively terminated by the user or the supervisor/project leader. Access fees are charged for full calendar months and the month of notice will be charged in full. Swift processing is conditional upon the user removing all personal items and returning all lab property.

Rules and Work instructions

Cleanroom Entry

Basically, two types of garment are used in the cleanroom. In the non-classified section (essentially materials analysis) a lab coat and lab shoes are mandatory, but a hairnet is highly recommended and cleanroom gloves should be worn in specific situations, such as handling samples or tools. Entrance to the classified area requires overalls, lab shoes and cleanroom gloves. Please note that additional protective wear is required when working with chemicals (see the section on chemicals).

Material in the Cleanroom

Users who need to store personal items (sample boxes, tweezers, notebooks and so on) in the cleanroom may request to have a blue storage box on a designated shelf in a cabinet. Lithography masks that are in use may be stored in mask boxes (one labelled box per user) on wire-rack shelves outside the lithography area. These storage provisions should eliminate the need to leave material on work surfaces in the laboratory. Items left behind will be removed and disposed of by lab staff. Only harmless material may be stored in the personal storage boxes.

Mobile phones and notepads (not laptops) are allowed in the cleanroom, but must be properly cleaned before entry to the classified section, where they should be carried openly (not inside overalls).

Staff Responsibilities

The MSL lab staff has the following functions and responsibilities:

- To provide technical support and maintain lab equipment.
- To maintain basic processes on important (frequently booked) equipment.
- To provide operator training and issue operator licences for lab equipment.

Figure D2: User dressed for non classified and classified sections respectively.

- To provide user support related to tool operation and work procedures.
- To supervise lab order and safety in the cleanroom.
- (If time allows: to provide commissioning services).

Some examples of services that should NOT be expected or required from the MSL staff:

- To clean or restore equipment to idle condition after user sessions.
- To provide user specific process development.
- To supervise research or development projects.

MSL does not guarantee the outcome of a project and does not take any responsibility for project delays or unexpected cost increases.

Working Hours

All approved users have access to the lab during extended working hours (regular lab hours), weekdays 07:00-18:00. Experienced users may be granted 24/7 access upon request. There should be clear reasons for this, such as a need to use heavily booked equipment, maintaining one's own tools or running prolonged processes.

Permission to work outside regular hours is always on the condition that the lab buddy system is respected. Wet benches with stationary baths may be used if the lab buddy is present in the same room, but filling or mixing of new chemicals is strictly forbidden outside regular working hours.

Interim access (prior to the introduction seminar) and access for undergraduate students is always restricted to regular lab hours (with the possible exception of highly restricted activities).

Normal staff hours are weekdays 08:00-17:00, and all users are recommended to carry out their lab activities when staff is available.

Chemicals

The Chemical Engineer (CE) is responsible for providing the chemicals, equipment and guidance needed for safe chemical processing. Always consult the CE (or stand-in) if there is any doubt as to the correct action. Contact data is available in LIMS and posted in the lab.

Protective Wear and Gowning Procedures

All chemical processing must be done in a ventilated work area (wet bench or fume hood). It is compulsory to use cover boots, a blue apron (pp type), latex gloves and a face shield when handling strong and/or warm chemicals or toxic chemicals in any concentration (such as hydrofluoric acid). For work involving any other chemical, latex gloves and a face shield must be used. Check your protective wear and dispose of any damaged item (rubbish box in acid fume hood). Put on the cover boots first, followed by apron, gloves and face shield (in that order).

After use, check carefully whether any of the protective wear is damaged or contaminated. Anything contaminated with HF or toxic chemicals should be disposed of according to instructions (see Waste Management). If damaged or contaminated with non-toxic chemicals, your cover boots or apron should be discarded (rubbish box in acid fume hood), as should damaged gloves. Everything else may be reused. Gloves should be washed and dried, face shields should be cleaned (with IPA, NOT acetone) and all items should be put in the right place for the next user.

Figure D3: Fume hood and wet bench – all options for working with chemicals. The picture at far right shows the full apparel for working with chemicals.

Non-Standard Processing

Any non-standard processing must be carefully planned and prepared with the CE. Search the literature for useful references and check with the CE whether all necessary chemicals, glassware, protective clothing and so on is available. (You may also obtain login information for KLARA, the chemical database, from the CE.) Any non-standard chemical that is not available in the cleanroom must be approved, ordered and introduced by the CE. Approval is also required for non-standard mixtures of standard chemicals.

Before initiating any new chemical process, you should read the material safety data sheets (SDS) for all chemicals that will be used and ensure that these are available in the KLARA database. Special attention should be given to the instructions regarding disposal of chemical waste. Present your proposed process (preferably a written step-by-step procedure from start to finish) to the CE for approval.

Select a suitable location, where all workstations are close together (contact the CE if you need assistance). Make sure all your chemicals are compatible with each other and with the equipment and materials you are to use. Check that all tools work properly and that you know the nearest location of all emergency aids (shut-down button, emergency alarm, emergency shower and so on) and emergency exits.

All non-standard chemicals MUST be marked with:

- the name of chemical (if mixed solution),
- the user's name,

- the user's telephone number,
- the user's affiliation (group/department/company),
- the date of preparation/introduction,
- a colour-coding dot.

Glassware containing chemicals are NOT allowed outside exhaust-ventilated areas. The container should be marked with the name of the chemical, its concentration and the appropriate hazard symbol.

After Processing

All tools and instruments should be returned to the proper location after use. Glassware should be rinsed and any marks should be removed with acetone before they are placed in the proper box for machine washing. Scales, magnetic stirrers and hotplates must be cleaned with cleaning solution (IPA 5 % / DIW 95 %) and returned to the cabinet in 3R47.

If required, baths should be emptied and washed (see specific instruction). Please note, baths with pumps should not be left empty; they should be filled with DIW which is then circulated until the pump is completely filled. Wet benches and fume hoods must be cleaned after use.

Bottles of chemical waste, contaminated wipers and other disposable labware should be disposed of according to instructions (see Waste Management).

Waste Management

Solid chemical waste and liquid chemical waste which is not allowed to be poured into the chemical drains should be removed to the waste storage room for delivery to the chemical waste station. All users are responsible for collecting, identifying and removing their chemical waste to the assigned shelf in a chemical cabinet.

Chemical waste containers MUST have a chemical waste label with the complete chemical names (abbreviations, trade names or chemical formulas are not permitted). If waste chemicals are mixed, the amount and concentration of each constituent must be listed on the container or in a log next to it. Be sure not to mix incompatible chemicals! Carcinogens (group A or B) should be identified. Use a suitable fume hood to carefully pour the chemical into the waste bottle and put the cap on tightly. Warm mixtures should be cooled to room temperature before they are moved to the chemical cabinet.

Wipers, protective wear and other disposable lab material contaminated with HF or toxic chemicals (other than cyanide) should be put in a yellow plastic bag with a chemical waste label (the label must first be filled in and clearly state the name of the contaminant) and moved to the designated place (fume hood in 3R75). Items contaminated with cyanide should be disposed of in the waste box in the toxic fume hood.

Broken glassware or wafers (sharp waste) should be disposed of in the appropriate container in 3R15 or 3R47:

- Clean glassware – plastic rubbish pail.
- Clean wafers – stainless steel rubbish can (with foot pedal).

For contaminated waste or metal waste, contact the CE for the correct action.

Decontamination

Any chemical spillage can harm people, equipment or the environment and must be cleaned up. Large quantities or unidentified spillages should be reported to the CE for proper action, but each user is responsible for taking the right action to remove his/her spillage.

A decontamination kit is available in 3R47 (classified section) and in 3R87 (non-classified section). When ordering a new chemical, it is important to check whether the equipment in this kit is sufficient in the event of a spillage. Please note that yellow roll wipers, used to absorb large amounts of chemicals, are not cleanroom-compatible and must be removed directly after use. Contaminated yellow wipers should be placed in a yellow bag and taken to the fume hood in 3R75 (see Waste Management), or to any suitable fume hood in the non-classified section. The CE must immediately be informed when a spillage has occurred.

In the event of a major spillage, or if there is any doubt about the correct action, the CE must be contacted directly. Tell other users to evacuate the contaminated area. You should remain available until the CE arrives.

Figure D4: Bags for HF and toxic contaminated wipes and items.

Specific MSL Chemicals

In addition to the chemicals listed in the main text (common to the Myfab labs), two hazardous chemicals are used in the MSL cleanroom.

"Cyanide" refers to a large group of chemical compounds containing the cyanide ion CN^-, which is responsible for cyanide poisoning. Cyanide can enter the body by inhalation, absorption (through skin or eyes) and swallowing. The degree of toxicity depends on how easily the cyanide ion is released from the rest of the compound (such as toluene diisocyanate or sodium thiocyanate). One of the most serious effects of cyanide is that it interferes with the action of certain enzymes and prevents the body's cells from interacting with oxygen. The symptoms of limited cyanide poisoning are basically the same as for lack of oxygen (dizziness, nausea, anxiety, vomiting).

Cadmium (Cd) is used in the form of cadmium acetate and the waste generated is cadmium sulphate. Contaminated wipers are disposed of in a ventilated yellow rubbish bag in 3R47 (handled by authorised personnel only). Cadmium may harm kidneys and lungs. Prolonged exposure causes cancer whilst more limited exposure may include sore eyes, coughing, headache, weakness, chills, fever and breathlessness.

Alarms and Emergencies

Three different alarm types may be triggered in the cleanroom (see table D1). A flashing red light with an audible signal is an evacuation alarm and calls for immediate evacuation through the nearest emergency exit. Be prepared to assist anyone in your vicinity who may need help. If you are at the site of a fire, that has just started and is not yet out of control, you should put it out if you are sure that you can do so. Be sure to alert others in your immediate vicinity, evacuate without changing or taking off any clothes or shoes and close the exit door. Move to the appropriate assembly point (see table below) and report all relevant information to MSL staff (for example, if you left an acid in a heated bath). Lab garments should be placed in boxes at the cleanroom entrance (house 1/floor 1). You will be notified by e-mail and a sign posted on the entrance door when you are allowed to enter the lab again.

The evacuation and fire alarms can also be triggered manually, which could be used in the event of a major chemical spillage. It is important to know that the fire

Alarm Type	Reason of the Alarm	What to do
Flashing blue light	Technical failure.	No user action required.
Flashing red light and siren	Evacuation alarm: Detection of hazardous gases within the lab or manual activation.	Evacuate the lab immediately! Reassemble outside the cleanroom entrance (house 1 floor 1 – if no signal outside the lab). Outside regular working hours, no reassembly or further action is required from the user.
Flashing red light and bell	Fire alarm: Detection of smoke / fire or manual activation.	Evacuate the building immediately! Reassemble at assembly sign on the northern parking lot. Do not re-enter the building until the flashing light has been turned off (acoustic signal may stop earlier).

Table D1: Possible reasons for an alarm and instructions on what to do.

alarm automatically summons the fire brigade, whilst the evacuation alarm does not have this function. If an ambulance is needed, this should be summoned by telephone (112). See fig. D5 for a lab layout with the location of the most important emergency aids.

Ångström Contact Information

The cleanroom has a few telephones available for lab-related calls (prefix outgoing calls with 00). Staff phone numbers are posted close to each telephone and should be used to get technical assistance during office hours (8:00-17:00). At other times, anything concerning the facility (ventilation, water, drain, light and so on) should be reported to Akademiska Hus.

Ångström address: Uppsala University
Ångströmlaboratoriet
Regementsvägen 1
752 37 Uppsala

Important tel no: Akademiska Hus emergency number: (018) 683 204

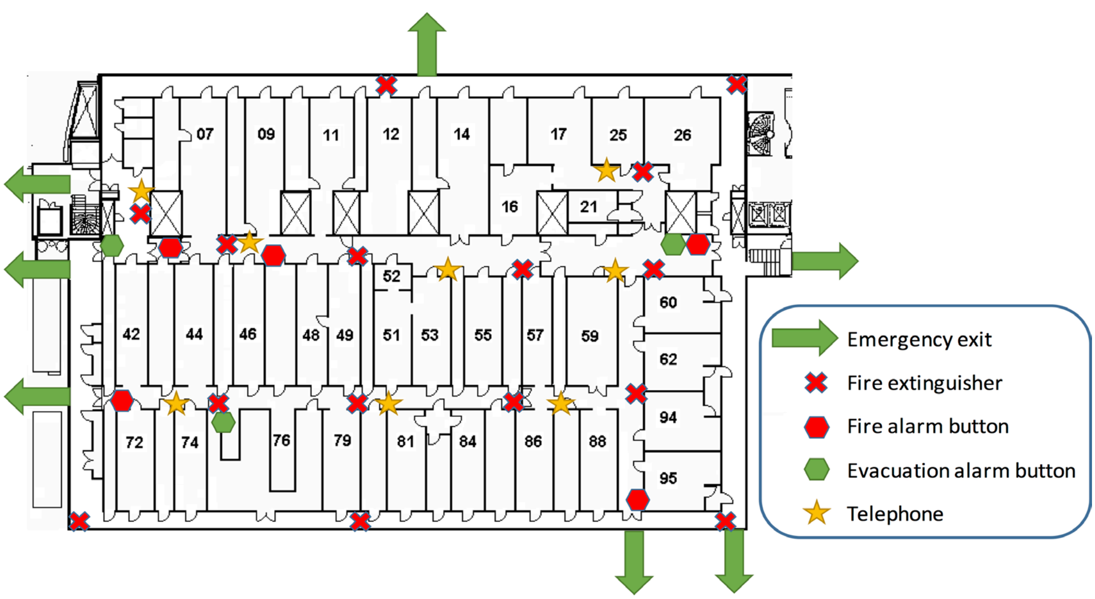


Figure D5: Location of emergency aids within the cleanroom.

Actions in case of a serious personal accident

- Call for help.
- Give first aid.
- Call for an ambulance.
- Give the address of your location (see below).
- If a chemical accident, also give the chemical name, concentration, volume, and exposure time, if known.
- Assist the injured person and send someone to meet the ambulance and paramedics.
- Guide the paramedics to the injured person.
- It is compulsory for at least one person to accompany the injured person to the hospital, if no lab staff is available, a user should do this.
- It is important that rinsing is continued during transportation to paramedics/hospital, using a handheld bottle.
- If no lab staff is available, contact a relative of the injured person. Each group has a register with this information.

Emergency number

112

Swedish Poison Information Centre

010-456 6700

Emergency contact information for the different Myfab sites:

Electrum: KTH, Royal Institute of Technology
Electrumlaboratoriet
Isafjordsgatan 22-24
164 40 Kista

Emergency/on duty number:
070-648 60 32

St Erik eye clinic:
08-672 31 00

MC2: Chalmers University of Technology
Microtechnology and Nanoscience - MC2
Kemivägen 9
412 96 Göteborg

Chalmers Fastigheter emergency number:
031-772 49 37

MSL: Uppsala University
Ångströmlaboratoriet
Regementsvägen 1
752 37 Uppsala

Akademiska Hus emergency number:
(018) 683 204

LNL: Lund University
Physics Department,
Division of Solid State Physics
Sölvegatan 14C
223 63 Lund

myfab

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