

INFORMATION PACKET
FOR
NEW USERS
OF THE
MICROFABRICATION LABORATORY (MFL)
At
Case Western Reserve University

The Center for Micro and Nano Processing
Case Western Reserve University
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MFL Safety Officer: Ed Jahnke

TABLE OF CONTENTS

TABLE OF CONTENTS.....	2
INTRODUCTION	3
CONTACT LIST.....	4
USER QUALIFICATION	5
EQUIPMENT OPERATION APPROVAL.....	6
PROCESS APPROVAL	7
GOWNING PROCEDURE.....	8
LAB EVACUATION PROCEDURE.....	9
CLEANROOM CONDUCT	10
LIST OF COMPRESSED GASES USED IN MFL.....	13
LIST OF LIQUID CHEMICALS USED IN MFL.....	14
EMERGENCY PROCEDURES.....	16

INTRODUCTION

The CWRU Microfabrication Laboratory (MFL) is one of the premier academic facilities in the US for the research, development, and prototype fabrication of silicon-based Microelectromechanical Systems (MEMS). The lab is approximately 5500 sq. ft. in size, about half of which is Class 100 cleanroom space. The MFL is professionally staffed and run as an independent cost center under the Electrical Engineering and Applied Physics Department. This resource is available to qualified to both CWRU academic users and to organizations outside CWRU through the Ohio MEMS-Net program, or MEMS-Exchange, a nationally available MEMS resource operated by the Center for National Research Initiatives (CNRI).

This information packet is intended to familiarize potential users of the MFL with established laboratory procedures and guidelines. After reading it, a potential user should know how to gain access to the lab, how to become qualified to operate equipment in the lab, how to gain approval for device fabrication, and whom to contact in case of emergency.

The regular clean-room operational hours are 8:30 am – 5:30 pm, Monday through Friday (Technicians on duty). With prior approval from the Lab Manager, other time may be allowed for qualified users (**at least two qualified MFL users will be present at all times**). Prior approval means e-mail or written communication, at least 24 hours in advance, with a schedule of proposed work tasks/equipment/processes to be used, to be presented to the Lab Manager at the time of your request.

It is important that all of the approval procedures described in this packet are followed exactly. They have been instituted to promote a *safe* and *efficient* work environment that supports a large number of different users and projects. It is the responsibility of each user to do his/her part in fostering this environment.

CONTACT LIST

All non-emergency concerns, requests, questions, or problems regarding lab operation may be directed to the MFL Manager, Li Chen. He may be contacted at the following location, phone number or using e-mail.

Li Chen
324 Bingham Building
(216) 368-0393
lichen@case.edu

IN CASE OF EMERGENCY CONTACT THE SECURITY OFFICE (x3333)

Be prepared to supply the following information:

- Your name
- The nature of the call (e.g., fire, acid spill)
- Location of the incident (320 B ingham)
- The phone number where you can be reached (presumably *not* the MFL)
- Any additional information requested.

Security will take the appropriate action, and can dispatch fire and emergency personnel. The MicroFabrication Lab is located in room 320 of Bingham Building. The telephone number is x4075. (**Note: this phone should not be used for personal calls at any time.**) A list is posted on the entrance to the lab that contains the individuals to contact when there is an emergency. Another phone number of interest is the **C.W.R.U. Department of Safety and Environmental Services (D.O.E.S.)**, x2907.

If it becomes necessary to contact MFL Staff through extraordinary means, please use the following digital telephone numbers: Otherwise, please use the phone directory on the next page.

Ed Jahnke	216-346-9821
Li Chen	216-308-7967

USER QUALIFICATION

In order to facilitate safe and efficient operation of the clean-room, each user must be officially qualified before he/she will be allowed to enter the lab. Qualification requires the awareness of the health and physical/chemical hazards present in the lab, knowledge of safe practices, and adherence to clean-room conduct guidelines (including gowning). Lab usage is considered a *privilege* that can be suspended or revoked at any time if established procedures and practices are not followed. The procedures in place are designed to protect the lab's users and equipment, and therefore it is in the best interest of each user to follow them.

To become an approved MFL user, you must have successfully completed EEAP322 or have equivalent experience. The procedure for qualification is as follows:

- Download and read this information packet.
- Make arrangements with the MFL Safety Officer to take a safety tour of MFL.
- Successfully pass the MFL Safety Exam to demonstrate basic safety knowledge and location of safety-related equipment in MFL. The test can be taken at your convenience any time after the safety tour.
- Complete a Service Center Requisition form, have your PI sign it, have your Department Administrator sign it, and then return to the Lab Manager. This form authorizes the MFL to charge your lab fees to the appropriate research grant.

Once qualified, you will be assigned a key card for lab entry and added to the "LabUsers" e-mail distribution list. New users are requested to label a hanger for their garments. You will also be given the password for use at the *MFL Equipment Reservation Page* (<https://mems.cwru.edu/reservation>), which will allow you to reserve equipment for fabrication processing in the clean-room lab.

EQUIPMENT OPERATION APPROVAL

After becoming an approved lab user, you will need to be trained to operate the equipment necessary for completion of your project. To be approved as an operator, a request should be submitted to the Lab Manager for each piece of equipment. (This can be done by e-mail.) The recommended first step in equipment training is to watch another approved operator use the machine. The Lab Manager will make arrangements for an initial training session with the MFL staff member who is responsible for the particular equipment. (Even if you know who this person will be, please do not approach them directly.) Further sessions are to be scheduled by the staff and the trainee at times that are mutually convenient; please recognize and respect the staff member's need to get other work done.

As a new operator, you will be responsible for learning the machine's routine operation and its safety hazards. This will involve in-lab training, out-of-lab reading, and in some cases completion of a qualification exam. You must demonstrate to the staff that you can operate the machine properly. After you have conveyed the necessary knowledge and skills, and the staff member is confident you are qualified to run the equipment, your name will be added to the "Approved Operators" list maintained by the MFL.

Each piece of equipment is under the responsibility of an MFL staff member. The staff is responsible for training of new operators, performing routine and emergency maintenance tasks, and monitoring process data for quality control and reproducibility (e.g., deposition rate, sheet resistance, film thickness). All operators will be *required* to make the appropriate process parameters from his/her run(s) available to the lab staff, typically by filling out process log sheets. Any deviation from the normal operation of the machine should be communicated to the appropriate staff member as soon as possible. This system is designed to maintain the processing equipment in good working order and track process history.

PROCESS APPROVAL

The third and final approval required before device fabrication is that of the entire process flow, or traveler. This is intended as a screening procedure to check for incompatible process sequences and to ensure that the processing equipment will not be damaged or contaminated. As with the other approval procedures, submission of a request to the Executive Director is mandatory **before beginning the process**. A detailed description of each process step should be included with the request, which should be reviewed by your PI prior to submission. Please list all process steps, highlighting those, if any, which will not be performed in the *MicroFabrication Laboratory Clean-room*.

Under normal circumstances, a decision will be rendered within one week, assuming all the necessary information has been provided. If the process is rejected, the reason(s) will be stated, and changes will be suggested. Once accepted, it is important to follow the process flow exactly; any deviations should be considered modifications of the approved process, and will therefore need to be approved formally—before fabrication continues—by the procedure described above.

GOWNING PROCEDURE

Proper gowning is an important aspect of clean-room maintenance. Done correctly, it serves to minimize contamination and particulate generation from the human body and clothing; humans are perhaps the “dirtiest” object in the clean-room. Remember that the airflow direction is from ceiling to floor (i.e., downward), thus the floor is where the most particulates reside. Therefore, gown from “top to bottom,” following the steps below in order; de-gowning should be done in reverse order.

- 1) If you have a coat or jacket, remove it *before* you enter the clean-room. There is a coat rack around the corner. Do not carry personal items into the lab.
- 2) As soon as you go into the entry room, sit on the bench (facing so the entry door is on your left) and put on a pair of shoe covers. Swing the foot with the shoe cover over the bench, then cover the other shoe and swing that over. Uncovered shoes are not to be worn at any point beyond this.
- 3) Enter the gowning room and put on a clean-room hood. *Make sure your hair is contained inside the hood.*
- 4) Step into coverall, tuck in hood flaps, and zip all the way.
- 5) Put on boots over legs of coverall.
- 6) Put on safety glasses or goggles. *Personal glasses (i.e., prescription lenses) offer sufficient protection;* contact lenses are not recommended, since chemical fumes can potentially permeate the lenses and get trapped against the surface of your eyes.
- 7) Put on vinyl gloves, taking care not to touch the outsides of them with your hands. Pull the gloves *over* the sleeve of your coverall.

You are now ready to enter the clean-room. **Do not touch the handle on the second door of the gowning room, or anything beyond it, without gloves.** The gloves, and inner (light blue) shoe covers are disposable, and should not be reused. The garments should be re-hung after use; these are collected weekly and sent to a clean-room laundry. If your gloves become dirty while you are inside the clean-room, replace them.

For your own safety, shorts, “Capri” style pant, skirts, sleeve-less blouses or shirts, and open-toed (or open sided, open heeled, etc...) shoes of any kind are not permitted in the clean-room. If you like to wear shorts during warm weather, it is recommended that you keep a pair of sweatpants handy to put on before you enter the MFL. If necessary, you may request to be assigned a locker within the MFL Gowning Room.

Additionally, if you are bringing a visitor on an approved Clean-Room Lab tour, they are not permitted to enter the clean-room space wearing any of the aforementioned clothing articles. It is the responsibility of the registered, approved lab-user to ensure that all guests are appropriately attired before entering the clean-room space, including safety glasses. THERE WILL BE NO EXCEPTIONS TO THIS RULE. The cooperation of all lab-users is expected and appreciated.

An approved Clean-Room Lab tour requires the consent of the MFL Faculty Director, MFL Lab Manager or MFL Chemical Safety-Hygiene Officer. Please make requests for clean-room tours as far in advance as possible. Please limit the size of “group” tours to no more than four (4) personnel. For larger groups, please consult the MFL Manager for appropriate resource considerations.

LAB EVACUATION PROCEDURE

The reasons for lab evacuation are listed below. If you are working in the lab while one of these situations occurs, you should notify others working in the area to evacuate and execute the above listed protocol. Valid reasons for evacuating the lab include:

1. Loss of power (do not pull the fire alarm)
2. Fire (engage the Fire alarm and Hazard Gas Shut-Off button)
3. Hazardous gas leak (engage the Hazard Gas Shut-Off button)
4. Hydrogen alarm sounds
5. Large chemical spill OUTSIDE a chemical hood (e.g., breaking a bottle of chemicals on the floor)
6. You notice a co-worker unconscious
7. Non-gas chemical exposure
8. Physical injury
9. Medical emergency
10. Loss of fume hood exhaust

In the event it is necessary to evacuate the MFL Clean-room, please use the following procedure:

1. **Immediately** stop what you are doing, aborting your process.
2. Proceed quickly to the closest available emergency exit. Do not run unless you perceive a life-threatening situation exists.
3. When exiting the lab, engage the Hazardous Gas Shutoff button. In case of fire, trigger the Fire Alarm.
4. Check to see that other lab-users are leaving the lab; if anyone cannot exit under his/her own power, call for emergency assistance. *Do not stop to remove your clean-room garments.*
5. After exiting the lab leave exit to the first floor of the Bingham Building and call Security at x3333 and notify them of the evacuation. Provide security personnel with all requested information.
6. Notify MFL Staff, if they are not present

Do not necessarily evacuate the lab for the following reasons:

- Small chemical spill inside a hood
- Inert gas leak

CLEANROOM CONDUCT

The next few pages highlight the *Approved* and *Non-Approved* clean-room behavior. The lists are not a comprehensive summary, so if you have a particular question, please ask someone. In general, if you are not sure whether or not you can do something, ***DON'T!***

CLEANROOM CONDUCT-GENERAL BEHAVIOR

Approved Practices

- Use common sense. If you see, hear, or smell something unusual, take the appropriate action.
- Adopt a “better safe than sorry” attitude.
- Report rules violations in confidence to Lab Manager.
- Report equipment problem, malfunction, or breakage to appropriate lab staff.

Non-Approved Practices

- Eating or drinking in the lab.
- Smoking in the lab.
- Running in the lab.
- Cover up any equipment problem or breakage. This will only make the situation worse.

CLEANROOM CONDUCT-CONTAMINATION CONTROL

Approved Practices

- Make sure hair is contained inside hood/mask.
- Walk on the tacky mats when entering the cleanroom.
- Replace gloves if they are dirty.
- Use clean-room paper and pens.
- Clean up after yourself. (Your workspace should be left cleaner than you found it.)
- Clean the outer surface of any material brought into the lab with isopropanol and a cleanroom wipe. This is to be done near the entry terminal. (NOTE: any materials brought into the clean-room must be pre-approved by the Lab Manager, except for wafer boxes and wafer holders.)

Non-Approved Practices

- Do not touch *anything* with bare hands.
- Do not touch skin, face, or hair with gloved hands.
- Do not bring paper or cardboard into the lab.
- Do not transfer quartz-ware¹ or Teflon-ware² between equipment, particularly the thin film furnaces in the Diffusion Aisle.
- Do not deviate from approved process sequence.

¹The Furnace Aisle contains stacks of LPCVD and APCVD furnace units for either depositing or growing silicon derivative thin films on silicon wafers. Within each of the furnace tubes are quartz “boats” or “cassettes” in which wafers are placed for in-furnace processing. In general, these wafer “boats” should **NEVER** be handled by hand or with vinyl gloves of any kind, in order to avoid leaving contaminants on the surface of the “boat” **OR** burning your hands and fingers (most furnaces operate at temperatures well in excess of 500C). At each furnace station, there is a special “paddle” for the boat that should always be used to remove wafer “boats” from the furnaces. In most cases, it

is a simple task to unload wafers directly from the wafer “boat” using the quartz-tip vacuum pens located next to each furnace stack. Be sure not to touch these quartz-tip vacuum pens, due to the possibility of contaminating the tip with material on your vinyl glove. Always allow for sufficient cooling of your wafers before removing them from the quartz boat and retaining them in your wafer process box. Usually, furnace programs go through a cool-down step to ambient temperature conditions for unloading purposes, but you should never assume that wafers are at room temperature if you are not familiar with the furnace program. Please consult with the MFL Staff member in charge of the furnace aisle, if you have any questions about furnace programs and any other questions about the equipment.

²Teflon-ware is to be used only the designated hood where it is located. Please do not move Teflon tanks or graduated cylinders from one hood to another at any time. While the likelihood of chemical contamination is rare, the MFL attempts to minimize any possibility of this occurrence.

Also, please do not remove the Teflon wafer “boats” used for wet chemical processing in the fabrication aisles from the designated aisles: this means that when you have successfully rinsed and dried chemically processed wafers, you should transfer the in process wafers to your process box (usually a black process box) and then remove them from the fabrication aisle for inspection, test and measurement, etc...

CLEANROOM CONDUCT-WAFER HANDLING AND STORAGE

Approved Practices

- Use vacuum pens to handle wafers.
- Use cassette-to-cassette “dump” transfers when applicable.
- Store “in process” wafers in sealed, labeled containers to be kept either in the storage bins or the nitrogen-plumbed dry-box.
- Label wafer boxes with: your name, PI’s name, run name/number, date started, your phone number. Unlabeled wafers will be discarded.
- Discard broken wafers in red SHARPS container and vacuum debris, or consult with MFL Staff for appropriate disposal measures. **NEVER DISCARD WHOLE OR PARTIAL WAFERS IN THE GENERAL WASTE STREAM, I.E., THE GARBAGE CANS. THIS IS A VIOLATION OF THE C.W.R.U. Department of Occupational and Environmental Safety STANDARDS AND MAY RESULT IN INJURY TO YOURSELF OR OTHER LABUSERS.**

Non-Approved Practices

- Do not touch wafers with hands or tweezers.
- Do not process partial or broken wafers.³
- Do not breathe on wafers.

³You may engage in limited processing of partial wafer pieces with the permission of the Faculty Director and Lab Manager. You must seek and receive approval **BEFORE** attempting any fabrication on partial wafers, or any wafers smaller or larger than 100mm (4”). Please be advised that the MFL has limited resources to assist such processing and fabrication.

CLEANROOM CONDUCT-CHEMICAL HANDLING AND STORAGE

Approved Practices

- Follow the procedures outlined in the appropriate documentation, and be aware of the health and physical hazards associated with chemicals in use.
- Pour chemicals slowly and carefully; add acid to water when mixing.
- Wear protective apparel when pouring chemicals. This includes a face shield, chemical-resistant gloves, sleeve guards, and an apron.
- Store, transport, and dispose of chemicals properly.
- Know the location of eye-washes, safety showers, and Material Safety Data Sheets (MSDS's).
- **Rinse all acid bottles three times in the hood where the chemical was used, before disposal.** Store empty **glass** acid bottles in the empty boxes located next to the acid cabinets in the rear aisle of the MFL Clean-Room. MFL Staff members will dispose of these boxes of clean, empty, glass bottles when the box is full. You may dispose of empty plastic bottles in the trash-cans located in the aisles.
- No organic solvents are permissible for use in the Chemical and Developer Hood. Organic solvents are permissible for use in the Metal Etch Hood during Lift-off Processing, but not when acid/base metal etching is being executed.
- In general, the use of organic solvents (particularly acetone) and the cleaning of parts, glassware, etc... should be done within the stainless steel Solvent Hood, located in the Sputtering Aisle.
- Return all organic solvents in large poly bottles to storage in the **Solvent Storage Cabinet** in the rear aisle of the MFL. All organic solvents in squirt bottles should be stored in the **Solvent Hood**.
- Be aware of the primary routes of entry into the body by chemicals are:
 1. Skin- Absorption
 2. Lungs- Inhalation (the fastest route for chemicals to enter the bloodstream)
 3. Mouth- Ingestion

Non-Approved Practices

- Do not open ANY chemicals outside of a fume hood.
- Do not use chemicals with which you are not familiar.
- Do not use unlabeled chemicals.
- Do not mix solvents and acids (explosive mixture!), or use these chemicals in proximity to each other, i.e. within the same hood.
- Do not assume drops of colorless liquid on the surface of a wet bench are water.
- Do not dispose of chemicals down the drain.
- Do not store partially filled containers of chemicals in hoods .

CLEANROOM CONDUCT-GAS HANDLING AND STORAGE

Approved Practices

- Always use approved gas carts to transport cylinders.
- Be aware of health and physical hazards associated with gases in use.
- Make sure gas cylinders are secured at all times.
- Know the locations of emergency gas shutoffs, emergency exits, and fire extinguishers; know emergency evacuation procedures.

Non-Approved Practices

- Do not use odor as a detection method for toxic gas leaks.
- Do not assume inert gases are not hazardous.

LIST OF COMPRESSED GASES USED IN MFL

<u>NAME</u>	<u>FORMULA</u>	<u>HAZARD CLASSIFICATION</u>
Ammonia	NH ₃	Corrosive, Toxic
Argon	Ar	Inert
Chlorine	Cl ₂	Corrosive, Toxic, Flammable
Diborane	B ₂ H ₆	Corrosive, Toxic, Flammable
Dichlorosilane	H ₂ SiCl ₂	Corrosive, Toxic, Flammable
Forming Gas	5% H ₂ in N ₂	Flammable, Explosive (see Hydrogen)
Freon 23	CHF ₃	Irritant, may cause frostbite, non-flammable
Freon 116	C ₂ F ₆	Irritant, may cause frostbite, non-flammable
Helium	He	Inert
Hydrogen	H ₂	Flammable, Explosive
Hydrogen Chloride	HCl	Corrosive, Toxic
Nitrogen	N ₂	Inert
Oxygen	O ₂	Flammable, Explosive
Phosphine	PH ₃	Toxic, Flammable
Propane	C ₃ H ₈	Flammable
Silane	SiH ₄	Pyrophoric ⁴ , Toxic
Sulfur Hexafluoride	SF ₆	Irritant, non-flammable

Notes:

- Inert and non-flammable gases, although non-toxic, can cause asphyxiation (suffocation) by displacing oxygen.
- ⁴Pyrophoric means spontaneously combustible in contact with air.
- ANY GAS NOT LABELLED "INERT" OR "NON-FLAMMABLE" SHOULD BE CONSIDERED TOXIC.
- Loss of nitrogen to turbo-pumps or cryo-pumps may result in pump in the buildup of toxic waste. Under no circumstances should non-MFL staff attempt any repair or restorative action on vacuum pumps associated with MFL equipment.
- Material Safety Data Sheet (MSDS) are available for review at any time. Please contact Paul Holter at extension 0393 for any safety information.

LIST OF LIQUID CHEMICALS USED IN MFL

<u>NAME</u>	<u>FORMULA</u>	<u>CATEGORY</u>	<u>HAZARD CLASS.</u>
Acetone	C ₃ H ₆ O	Organic Solvent	Flammable, Irritant
Aluminum Etchant	Acid Mixture	Acid	Flammable, Corrosive
Ammonium Hydroxide	NH ₄ OH	Base	Corrosive
Buffered Hydrofluoric Acid	HF + NH ₄ F	Acid	Corrosive, Toxic
N-Butyl Acetate	C ₆ H ₁₂ O ₂	Organic Solvent	Flammable, Irritant
HMDS (hexamethyldisilazane)	[(CH ₃) ₃ Si] ₂ NH	Organo-silicon	Flammable, Corrosive ⁵
Glacial Acetic Acid	CH ₃ COOH	Acid	Flammable, Corrosive
Hydrochloric Acid	HCl	Acid	Corrosive, Toxic
Hydrofluoric Acid	HF	Acid	Corrosive, Very Toxic ⁶
Hydrogen Peroxide (30%)	H ₂ O ₂	Oxidizer	Irritant
Isopropanol	C ₃ H ₇ OH	Organic Solvent	Flammable, Irritant
Methanol	CH ₃ OH	Organic Solvent	Flammable, Irritant
1-Methyl-2-Pyrrolidinone	C ₅ H ₉ NO	Organic Solvent	Flammable, Irritant
Nichrome Etchant	Acid Mixture	Acid	Flammable, Corrosive
Nickel Etchant	Acid Mixture	Acid	Flammable, Corrosive
Nitric Acid	HNO ₃	Acid	Corrosive
Photoresist (PR) ⁷	Proprietary	Organic Solvent	Flammable, Irritant
PR Developer	Proprietary	Base	Corrosive
Polyimide resist ⁸	Proprietary	Polyimide	Flammable, Irritant
Sulfuric Acid	H ₂ SO ₄	Acid	Corrosive

⁵This chemical will react with water to produce toxic vapors.

⁶Hydrofluoric acid (HF) burns can take as long as 24 hours to be felt. If you believe that your skin has been exposed to HF—even if you do not feel a burn—rinse the area thoroughly (30 minutes) and seek medical attention. This acid is perhaps the most dangerous chemical on the list.

Although not shown, oil from vacuum pumps may be considered hazardous, depending on the gases being pumped. Such pumps are purged with nitrogen to avoid the potential danger of explosion due to desorption of trapped gases.

⁷Photoresist materials used in the MFL differ only in the viscosity of the mixture. Please consult with Paul Holter to review a complete list of PRs used in the MFL, the material properties and hazards.

⁸Polyimide materials used in the MFL also differ only in the viscosity of the mixture and whether or not the material is photo-definable like traditional photo-resist materials. Please consult with Paul Holter to review a complete list of polyimides used in the MFL, the material properties and hazards.

BASIC EMERGENCY PROCEDURES

The following procedures are designed to aid users in dealing with the most common emergency situations you may encounter in the MFL Clean-room. A more complete written description may be found in the MFL **Chemical Hygiene Plan**, and can be reviewed with the MFL Chemical Safety-Hygiene Officer, MFL Manager, or the MFL Faculty Director. *The procedures are not designed to replace certified programs of first-aid methods (normally available through the American Red Cross Association) or spill control methods lab-users may desire to learn.*

NOTE: *Lab-Users are not required to administer or assist in first-aid to accident victims in the MFL at any time.*

Chemical Splash affecting the eyes:

1. Move the victim to the nearest ***Emergency Eye Wash/Emergency Shower*** station.
2. Flush eyes with water for at least 15 minutes. Be sure that the eyelid is pulled back, and the eye is exposed as completely as possible.
3. Seek immediate professional medical attention.

Chemical Spill affecting other body parts:

1. Move the victim to the nearest ***Emergency Eye Wash/Emergency Shower*** station.
2. Flush the affected body part for at least 15 minutes
3. Remove affected clothing **AFTER** flushing with water
4. Seek immediate professional medical attention.