

SEAS CLEAN ROOM POLICY AND PROCEDURES

Rev. May-2008-1

The following procedures and policies have been developed with the consideration and the cooperation of the Dean of School of Engineering and Applied Science, SEAS clean room staff, SEAS clean room faculty advisory committee, the Office of Environmental Health and Safety and the Provost's Office. Every effort has been made to accommodate the needs of the research community while ensuring for prudent and necessary budget controls, as well as, the maintenance of a strong culture of safety.

The SEAS clean room management is fully empowered to implement and enforce policy including disciplinary protocol.

As with the Clean Room Handbook, this is a living document and will evolve over time with our experiences. Questions or comments regarding the content of this document should be submitted through the clean room staff at regularly scheduled user meetings. Changes to this documents will be posted on the clean room web site and distributed to the user community

User Fees

Every effort has been made to develop a chargeback policy that is fair and consistent and adheres to all generally accepted accounting principals.

Time Keeping

All clean room users are required to swipe their proximity card at the main entrance reader upon entering and also upon exiting the facility this applies regardless if the door is previously open for someone else.

Although there are ways to defeat the time keeping system, clean room management and the Dean of Engineering fully expect honest and professional behavior to prevail.

Random review of surveillance data will be conducted to validate compliance. Intentional failure to comply with this protocol will result in the incident being treated as a Level 2 non-safety violation.

Hourly Rate

The hourly rate to access the clean room is \$30 per hour. This rate covers most of the expenses incurred to supply and staff the clean room. The hourly rate will be billed in 15 minute increments.

Additional Fees

A select few pieces of process equipment incur additional costs to insure specified performance and operation of a properly maintained machine. Therefore these machines will carry a premium for use as outlined below. Qualified users are required to schedule time on this equipment through Coral, which will be used to generate user reports.

Oxford 80 fluorine RIE	\$40/hr.
Oxford 100 chlorine RIE	\$65/hr.
TRE maskmaker	\$250/mask
Heidelberg maskmaker	\$250/mask

The TRE and Heidelberg maskmaker per mask charges include one (1) test grade plate for optimizing process and one (1) master grade plate for final mask.

Annual Maximum

The current cap for all clean room charges is set at \$10K per user per 12-month period. Once the cap is reached, all subsequent charges incurred during the remainder of the same 12-month period by that user are then reduced to 20% of current rates. At the end of the 12-month user period all rates are reset to normal.

Review

User fees will be reviewed by the Business Office once per fiscal year or more frequently as warranted. Recommended fee adjustments are initiated by the Business Office and forwarded to the Dean of Engineering for review and approval.

Clean Room After Hours Policy

Hours of Operation

The clean room is open to unrestricted operations Monday thru Friday 8AM until 6PM, the clean room is closed to all users on the following dates: New Years day, Thanksgiving day, and Christmas day.

After Hours

After hours are defined as hours beyond 8:0am – 6:00pm Monday thru Friday. Anyone who needs to work in the clean room after hours is required to adhere to the following protocols, without exception. *Failure to comply with these protocols will result in a level 1 or 2 safety violation. (please see section on discipline for explanation)*

Protocols for after hours work in the clean room

- A clean room user must accumulate 30 hours or more of clean room experience before being cleared for after hours entry. This means a clean room user's ID badge will only work during normal business hours until this requirement has been met.
- A clean room user may use the clean room after hours for allowed operations under the condition that they are accompanied by another qualified clean room user or they provide for another person, or remote buddy, to be responsible for checking up on them at least once per hour.
- Until an improved system is implemented, there will be a sign in log for after hours, the log will include the name of the clean room user, the name of the designated buddy, operations to be performed, time in and time out.
- Random audits of after hours logs and surveillance will be conducted to validate safety compliance.

Allowed Operations

The following tools and processes have been approved for unrestricted after hours use, in conjunction with above protocols.

- Lithography tools: vacuum bake/vapor prime, resist spin/bake, mask alignment/exposure, development, microscope inspection
- Develop plates using APT plate developer
- Operate vacuum deposition systems
- Operate metrology tools: Alpha Step, Ellipsometer, Nanometrics, microscopes
- TRE and Heidelberg mask makers
- MCS plasma asher
- Oxford 80 fluorine RIE/ICP
- Oxford 100 chlorine RIE
- GSI PECVD
- Solaris RTA
- CVD furnace
- Lindberg furnace

Restricted Operations

The following operations require another qualified user is present in the clean room because of the potential for an emergency situation requiring immediate assistance. *Since charges are accrued for any clean room user entering the facility, it is strongly suggested to co-ordinate with someone with a mutual schedule from the same research group.*

- Hot/strong acid/base chemical work (requiring face mask, apron, heavy gloves)
- Heated solvent work.
- HF use (requiring face mask, apron, heavy gloves)

The following tools are currently available only during normal operating hours:

- Critical point dryer

Chemical Safety and Handling Procedures

The following document provides detailed instructions for every phase of chemical handling in the Yale Cleanroom from storage through disposal. These procedures are designed to ensure the safety of everyone who uses the facility as well as to comply with federal and state regulations. Everyone who is admitted to the facility should be familiar with these procedures. Reading and knowing these procedures in no way qualifies you to enter or do any work in the cleanroom, although it is a pre-requisite. Further, some equipment discussed in this document, namely the *CMOS hood*, has additional procedural requirements that should not supersede these procedures but must be followed in addition.

Fresh Chemicals Storage and Transporting

Bottles of fresh chemicals are to be stored in one of the two chemical pass-through cabinets or in the small cabinets under the proper benches. The chemical bottles should be wiped down prior to being placed in the pass-through from the outside hallway to minimize particulates. Bottles of fresh acid or caustic chemicals other than developer should be transported from the cabinet to the hoods using a rubber bucket and one heavy nitrile glove. This allows the user to have one free hand to open the door and one protected hand to carry the bucket. Bottles should be returned to the proper storage location immediately after use. Rubber buckets should be left near the pass through cabinets.

Acids:

Fresh acids should be stored in the trays on the 2nd and 3rd shelves of the corrosives pass-through. There is also room for ~ 8 bottles of acid under the *Acid Hood*. To avoid unnecessary searching for a particular acid, commonly used acids will have a specific location in one of these cabinets and the cabinets will be labeled with this information. These chemicals and their locations are designated on the *Chemical Storage Chart*. Other bottles must be stored in the corrosives cabinet. Over time, we may find that the frequently used chemical list changes and we will adjust the *Chemical Storage Chart* accordingly.

Bases/Caustics:

Fresh bases and caustic-based chemicals should be stored in the trays on the top shelf of the corrosives pass-through. This includes developers as well as strong bases. There is room for ~8 bottles of caustics under the *Base/ Caustics Hood*. Developers will be stored on the left side and strong bases will be stored under the right side. As with the acids, each chemical will have a specific location in one of these cabinets and the cabinets will be labeled with this information. These chemicals and their locations are designated on the *Chemical Storage Chart*. Developers will also be stored under the right hand cabinet of the *Solvent Hood*.

Hydrogen Peroxide:

Hydrogen peroxide should be stored with the bases in the corrosives pass through. It may also be stored in the right hand cabinet of the *Base Hood*.

Solvents:

Fresh solvents should be stored on the top two shelves of the flammables cabinet. They will also be stored in the left hand cabinet of *Spinner Hood #1* and the left side of the *Solvent Hood*. Some SU-8 related solvents such as SU-8 developer and EBR PG will be stored under the left side of the *MEMS Hood*. See the *Chemical Storage Chart* for details.

Photoresists, E-beam resists, Primers:

Fresh bottles of photoresist should be stored in the explosion-proof refrigerator in the lithography bay to preserve their lifetime. They may also be stored temporarily on the 2nd shelf of the flammables cabinet. Small bottles in-use may be stored on the bench top of *Spinner Hood #1* and *Spinner Hood #2*. E-beam resists should be stored on the second shelf of the flammables pass-through. Photoresist primer should be stored on the second shelf of the flammables-pass through. Epoxy based resists such as SU-8 as well as fresh bottles of lift-off resists should be stored under the right side of the *MEMS Hood*.

CMOS bench:

This bench is listed separately because it is the only place where acids, bases, and solvents are to be used in the same hood. There is room for a few commonly used chemicals in the cabinets under the hood. Fresh and waste acids will go in the left hand cabinet. Fresh and waste solvents will go in the right hand cabinet. See the *Chemical Storage Chart* for details. The two middle cabinets are used to store the carboys for the two process tanks.

Personal Protective Equipment

Various tasks in the cleanroom carry various requirements for using personal protective equipment. The purpose of these rules is not to hinder your work but to keep you and those around you safe. Proper PPE will greatly reduce the risk of an injury should you or someone around you cause a chemical accident. Each chemical bench has specific PPE requirements for anyone working there. These requirements also apply to someone observing work at that bench.

General Cleanroom areas:

Users are required to wear safety glasses at all times when they are in the cleanroom. Nitrile or vinyl gloves are also mandatory.

Transporting Chemicals:

Every effort has been made to minimize the number of times a user needs to carry a bottle from the cabinets to the benches or vice-versa. Even so, we have a limited amount of storage space under the benches and thus you will probably have to do this sometimes. At a minimum you must be wearing regular nitrile gloves and safety glasses before retrieving chemicals from the cabinets. This is sufficient for solvents and developer. These may be safely transported without the rubber buckets.

Acids and caustics (besides developer) require slightly more caution. Users should get a single green nitrile glove and a rubber bucket. Wearing the green glove, place the chemical into the bucket and carry it using the gloved hand. The ungloved hand should be used for opening the door to avoid contaminating the button. This procedure should be repeated when returning chemicals to the cabinet. This method should also be used when transporting chemicals to the MOS hood. It will minimize the likelihood of dropping a bottle between the cabinet and the hood.

Acid hood:

All users working or observing at the acid hood are required to wear safety glasses, a face shield, a chemical apron, and the heavy green nitrile gloves. Even if you are using what you believe are "less-dangerous" chemicals you must still use the full PPE because of the possibility that someone else has left "more dangerous" chemicals in the hood and the likelihood that the surfaces of the bench are contaminated with these chemicals.

The apron should be put on first with the side labeled "Chemical side" facing the bench, followed by the face shield, and finally the green gloves to avoid touching the apron and face shield with contaminated gloves. Green gloves should be removed before removing shield or apron. Rinse and dry any contaminated gloves before removing them.

Base Hood:

All users working or observing at the base hood are required to wear safety glasses, a face shield, a chemical apron, and heavy green nitrile gloves. Even if you are using what you believe are "less-dangerous"

chemicals you must still use the full PPE because of the possibility that someone else has left “more dangerous” chemicals in the hood and the likelihood that the surfaces of the bench are contaminated with these chemicals.

The apron should be put on first with the side labeled “Chemical side” facing the bench, followed by the face shield, and finally the green gloves to avoid touching the apron and face shield with contaminated gloves. Green gloves should be removed before removing shield or apron. Rinse and dry any contaminated gloves before removing them.

MOS Hood

The MOS hood is unique in that it is used for acid- and caustic-based chemistry as well as solvents and thus it presents more hazards than any of the other benches.

All users working or observing at the MOS hood are required to wear safety glasses, a face shield, a chemical apron, and heavy green nitrile gloves. Even if you are using “less-dangerous” chemicals you must still use the full PPE because of the possibility that someone else has left “more dangerous” chemicals in the hood and the likelihood that the surfaces of the bench are contaminated with these chemicals.

The apron should be put on first with the side labeled “Chemical side” facing the bench, followed by the face shield, and finally the green gloves to avoid touching the apron and face shield with contaminated gloves. Green gloves should be removed before removing shield or apron. Rinse and dry any contaminated gloves before removing them.

Spinner Hoods #1 and #2:

Users at the spinner benches must wear at least safety glasses and regular nitrile gloves.

Solvent Hood:

Users at the spinner benches must wear at least safety glasses and regular nitrile gloves. Heavy nitrile gloves and face shield are strongly recommended when using heated solvents.

Chemical pouring and use procedures

Chemicals in-use

All chemicals in the benches must be properly labeled and covered whenever you are not actively using them (Pouring, emptying, stirring). This is not optional. It is a rule in all labs at Yale and complies with federal and state regulations. This is to ensure that if you have to leave the area quickly in the event of an accident, fire alarm, phone call or other interruption that there won't be unknown chemicals left in the bench. Label your glassware and find something to cover it with before you pour your chemicals so you don't forget. Be sure that there is a proper waste bottle available before you pour your chemicals. If there is not, this may indicate that you are using chemicals that have not been approved in the cleanroom or a mixture that has not been approved so ask the staff before you proceed. If there is no waste bottle for your chemicals but you are sure it is an approved chemical or mixture, start a new waste bottle as described below in the *Chemical Waste* section.

Process Tanks:

The process tanks have seen very little use so far because they generate such large quantities of waste. Several of these tanks will be filled with standard solutions and left full at all times. They will be clearly labeled as such and must remain covered at all times when they are not in use. The chemicals will be changed periodically as needed. This will minimize the amount of waste generated as well as to minimize the handling of dangerous chemicals and provide the convenience of ready-to-use baths. These baths should never be emptied or refilled by users unless directed to do so by a staff member. The details of each of these baths will be available on the *Chemical Storage Chart*.

The front tank in the *Acid Hood* will be filled with a buffered oxide etch (BOE) solution. This is useful for stripping oxide from wafers. The rear tank will be filled with Nanostrip. This is a stabilized version of "Piranha Solution" and is useful for stripping organic residue from wafers. The nanostrip solution in the tank may be heated up for use. It has a lifetime of weeks if it is only heated during use. This should allow us to minimize the usage of "Piranha solution." Samples should be lowered into BOE or nanostrip bath using a long-handled boat. After etching is complete the boat should be removed and immediately placed into the cascade-rinser for several minutes until resistivity monitor reads ~16 M-Ohms. The boat can then be removed and the rinsing turned off and drained.

The heated process tank in the *Solvent Hood* will be used as a photoresist stripper bath. It will be left full of organic photoresist stripper such as AZ300T or 1165 that can be heated as needed. It will be changed periodically as needed (~monthly).

The heated ultrasonic tanks in the *MEMS Hood* and *Spinner Hood #1* are to be filled with water as needed for ultrasonic cleaning. No other chemicals may be added to the bath. Samples shouldn't be placed directly into the bath but instead, should be placed in a beaker and suspended in the bath using the baskets provided. These tanks may be left full of water and will be periodically drained and refilled.

Empty bottles:

When you empty a bottle of fresh chemical it is your responsibility to dispose of the empty bottle. You must rinse the bottle with DI water at least 3 times. The rinsate should be poured down the drain. After rinsing you must deface the label of the bottle. If possible you should peel off the label. If not, cross it out with a permanent marker. Then you may place the bottle under the shelf between the *Acid Hood* and *Solvent Hood* to be reused as a waste bottle.

Chemical Waste

In the cleanroom we generate a significant amount of chemical waste. It is important to ensure that this waste is properly handled, labeled and stored to avoid injury and to comply with state and federal regulations.

Chemical Waste Storage

Chemical waste is stored in two places in the cleanroom. The first is at the point of use in the hoods. There is space for a limited number of bottles (6 or less) of frequently used waste in each hood. This is the safest and most convenient place for waste bottles that are in-use so that they don't have to be transported very often. The hoods are exhausted and provide appropriate secondary containment for their respective waste chemicals. Each hood will have a list of waste bottles that may be stored on the bench top. Other waste streams that are generated less frequently will have to be stored on the bottom shelf of the appropriate cabinet/pass through. The corrosives cabinet has two trays on the bottom shelf that provide secondary containment for acid and caustic waste. Acids should be placed in the tray on the left side and caustics on the right side when looking at the cabinet from inside the CR. Users are responsible for transporting all full waste bottles from the hoods to the cabinets. As with fresh chemicals, this should be performed using the rubber bucket and heavy nitrile glove when acids or strong caustics are involved.

Starting a New Waste Bottle

Before starting a waste bottle, ensure that there is not already a waste bottle for your chemistry in the hood or in the cabinet. If you are sure there is no waste bottle, get the proper label from the file folder on the shelf. If no label is available, call the staff to print out more labels. This may also be an indicator that the mixture you wish to generate is either incompatible or isn't approved for use in the cleanroom. If you are unsure, ask the staff.

Find a bottle that is compatible with your waste from beneath the wire shelf. Check to make sure that the bottle has been rinsed and affix the waste label to the new bottle. If you are using a chemical mixture containing hydrogen peroxide you must use a vented cap. A plastic bottle must be used for mixtures containing hydrofluoric acid (HF). If no appropriate waste bottle is available, call the staff to get you one. Do not start using chemicals until you know that a waste bottle is available.

Pouring out Waste

When you are finished with your chemicals you must pour them into the proper waste container. Place the waste bottle next to the sink and put the funnel in the mouth of the container. Carefully pour the waste into the funnel making sure you don't overfill the bottle. Once your container is empty, remove the funnel from the waste container making sure you don't drip the residue from the funnel onto the bench-top or the outside of the bottle. Thoroughly rinse the funnel in the sink to remove chemical residue. If you dripped chemical on the outside of the bottle, put on the cap then put the bottle in the sink, rinse it off and dry it with a wiper. Clean any spills from the bench-top using water and a wiper. Rinse the contaminated wiper in the sink and squeeze out the water before disposing of it in the trash. Finally, rinse out your glassware thoroughly before removing it from the hood. When you are finished, rinse off the green gloves in the sink and blow or wipe them dry before removing them. If the waste bottle is not full and is one of the ones stored in the hood you may leave it in the back of the hood. If it is full, or it is not to be left in the hood, transport it to the cabinet using the rubber bucket and glove as described previously.

Discipline

The clean room has enjoyed an excellent record of safety over the past 20 years, a tribute to the level of professionalism we have at Yale. On the rare occasions we must take disciplinary action, it is imperative we follow a procedure that ensures fairness and a quick resolution.

Every CR user is responsible for ensuring that laboratory safety procedures and protocols are followed. All users and staff members have the authority and responsibility to take immediate action to mitigate a safety or policy violation and to report it to the manager in charge.

Safety and Chemical Handling Violations

Levels of safety and chemical handling violations and immediate staff actions

Level 1. *User knowingly disregards safety and/or procedures, resulting in injury to self or another.*

Staff action: Immediately revoke clean room privileges, deactivate access indefinitely, convene safety review board

Level 2. *User unknowingly disregards safety and/or procedures, resulting in injury to self or another.*

Staff action: Immediately revoke clean room privileges, deactivate access for 3 month minimum, convene safety review board

Level 3. *User knowingly disregards safety and/or procedures, not resulting in injury to self or another.*

Staff action: Immediately revoke clean room privileges. Deactivate access for at least 4 weeks, generate record of discussion (RoD) within 10 days, take corrective actions, restrict future access.

Level 4. *User unknowingly disregards safety and/or procedures, not resulting in injury to self or another.*

Staff action: Immediately revoke clean room privileges. Deactivate access for at least 3 weeks, generate record of discussion (RoD) within 10 days, take corrective actions, restrict future access

Response to Violations resulting in injury (Levels 1 and 2)

Safety Review Board

A safety review board is reserved for laboratory incidents resulting in injury. It will convene within 10 days of the incident and will be responsible for collecting and documenting evidence and accounts of the incident. The board has the discretion to call any and all parties involved to clarify actions and behavior leading to the incident. Board members will convene in private to decide on corrective actions and the accused user will receive a decision in writing. The board will also generate an incident report along with any notices or policy changes needed to prevent future accidents. Incident reports are intended as educational tools, thus, names will be omitted prior to filing for public display.

The safety review board will be made up of a panel of the following people

- FoE manager
- CR director
- faculty advisor
- CR manager
- OEHS representative

Response to Violations not resulting in injury (Levels 3 and 4)

The CR manager-in-charge is responsible for taking immediate action and will begin investigating the incident. An investigation proceeds as follows:

- Interview person accused of violation
- Interview witnesses
- Consider immediate action
- Review with violator's faculty advisor
- Issue a record of discussion (RoD) report within 10 working days
- Meet with violator to report final disposition
- RoD is signed by violator, CR manager, faculty advisor
- CR manager to hold original RoD

Record of discussion

The RoD report will contain, a brief description of the violation, the actual or potential outcome due to the violation, an account of any interviews, likely reasons for violation, corrective actions, signatures of involved parties. Multiple RoD's will result in stiffer penalties for subsequent offenses.

Protocol and equipment Operations Violations

Levels of violations of protocols and equipment operations and immediate staff actions

Level 1. *User knowingly disregards training and/or procedures, resulting in damage or contamination to equipment or facility*

Staff action: Immediate indefinite disqualification from equipment damaged, assess damage, convene non-safety review board

Level 2. *User unknowingly disregards training and/or procedures, resulting in damage or contamination to equipment or facility,*

Staff action: Immediate 4 week disqualification from equipment damaged, assesses damage, convene non-safety review board, generate record of discussion (RoD) within 10 days, take corrective actions, limited and monitored access to equipment

Level 3. *User knowingly disregards training and/or procedures, not resulting in damage or contamination to equipment or facility.*

Staff action: Immediate 3 week disqualification from equipment, generate record of discussion (RoD) within 10 days, take corrective actions, limited and monitored access to equipment

Level 4. *User unknowingly disregards training and/or procedures, not resulting in damage or contamination to equipment or facility.*

Staff action: Immediate 2 week disqualification from equipment, generate record of discussion (RoD) within 10 days, take corrective actions, limited and monitored access to equipment

Response to violations of training and or protocols resulting in damage or contamination of equipment or facility (Levels 1 and 2)

Non-Safety Review Board

A non-safety review board is reserved for laboratory incidents resulting in costly damage or contamination to facilities and or equipment. It will convene within 10 days of the incident and will be responsible for collecting and documenting evidence and accounts of the incident. The board has the discretion to call any and all parties involved to clarify actions and behavior leading to the incident. Board members will convene in private to decide on the appropriate cost liability and responsibility.

The non-safety review board will be made up of a panel of the following people

- FoE financial officer
- FoE business manager
- CR director
- faculty advisor
- CR manager

Response to violations in training and or protocols not resulting in damage or contamination of equipment or facility (Levels 3 and 4)

The CR manager-in-charge is responsible for taking immediate action and will begin investigating the incident. An investigation proceeds as follows:

- Interview person accused of violation
- Interview witnesses
- Consider immediate action
- Review with violator's faculty advisor
- Issue a record of discussion (RoD) report within 10 working days
- Meet with violator to report final disposition
- RoD is signed by violator, CR manager, faculty advisor
- CR manager to hold original RoD

Record of discussion

The RoD report will contain, a brief description of the violation, the actual or potential outcome due to the violation, an account of any interviews, likely reasons for violation, corrective actions, signatures of involved parties. Multiple RoD's will result in stiffer penalties for subsequent offenses.