Clean Room Handbook
Rev. 2.1.3

Center for Microelectronic Materials and Structures
School of Engineering and Applied Science
Yale University

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(Clean room website URL- under construction)

The publication of this cleanroom user's handbook is motivated by the desire and need to inform and guide the new or returning cleanroom user in the rules, features, and guidelines for the successful conduct of research in the facility. This will be a live document; as our cleanroom organization matures, and as we make the inevitable changes and additions to the facility, the contents of this guide will change with it.

Introduction

Brief history of the Becton CR

The “original” Becton Cleanroom was built in 1988 for $1.2M. Its pertinent design specifications:

2,600 square feet
One bay Class 100 with the remainder Class 1,000
Temperature 68 ±4° F
Humidity 40 ±5%
Staff: 1 Technician/manager
Entire budget paid by user fees
Building facilities maintained by physical plant

The original faculty founders were Dick Barker, T.P. Ma, Dan Prober, and Bob Wheeler

Over the course of the last 20 or so years, at least 15 Faculty Users from 5 departments have relied on the cleanroom:

•Richard Barker (EE)
•T.P. Ma (EE)
•Jung Han (EE)
•Mark Reed (EE)
•Hur Koser (EE)
•Janet Pan (EE)
•Jerry Woodall (EE)
•Ainissa Ramirez (ME)
•David LaVan (ME)
•Charles Ahn (AP)
•Rob Schoelkopf (AP)
•Dan Prober (AP)
•Michel Devoret (AP)
•Jack Harris (Phys)
•Fred Sigworth (Med)

Estimated research relying on cleanroom usage: $ 3-4 M/yr total, with quantum computing alone accounting for approx. $ 2 M/yr, with 100% reliance on the cleanroom.

In early 2005, Dean Fleury formed an Executive Committee composed of Profs. T.P. Ma, J. Han, and R. Schoelkopf. The committee issued a report (6/05) finding significant problems with Becton cleanroom. These problems included:

1) Environmental systems failing
    -Air handler past useful life, accumulates water
    -Cleanroom environment no longer meets specs
    -Dehumidifier (DX coil) removed sometime in 2003
    -Pneumatic controls antiquated, no logging of data

2) Potentially serious safety issues
    -Toxic/flammable gas storage not up to code
    -Electrical code violations
    -Wet benches: too few, flammable, ventilation inadequate

3) Tool set out of date, maintenance problematic
    -No plasma etching, mask making …

4) Understaffed, no direct university support!

The University responded in several ways:

1) Two new CR staff positions were authorized and funded by the Provost's office

2) The purchase of approx. $ 1.7M in new cleanroom tools was authorized and funded by the Provost's office

3) A comprehensive cleanroom redesign was begun in 2005. Midwest Cleanroom Associates (MCA) were selected to serve as consultants and commissioning agents on the subsequent renovation project

4) The major renovation project was begun 3/07 and completed by 09/07

5) Certification and commissioning completed by 10/07

Cleanroom Specifications

2007 Yale FOE CR 2.0 Design Specifications

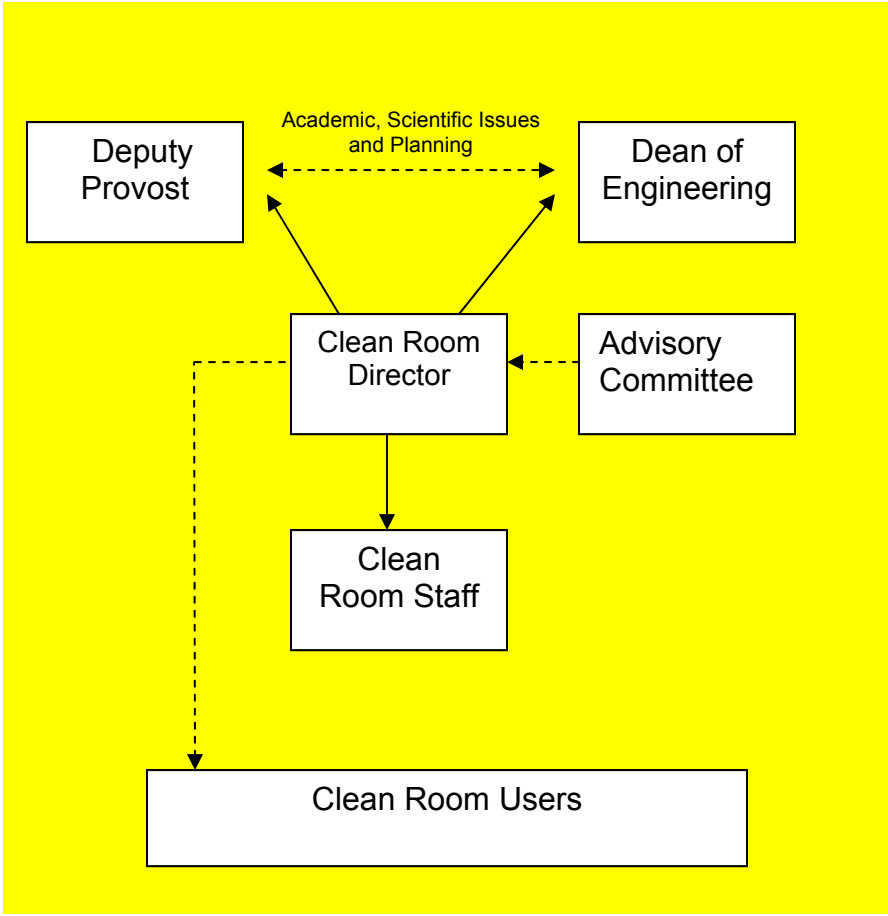
Temperature:	68 ± 2° F sensed at 10 points, with remote telemetry and logging
Relative Humidity:	45 ± 5 % sensed at 10 points, with remote telemetry and logging

(source: Basis of Design, Midwest Cleanroom Associates, April 13, 2006)

Total make up air flow, scfm	17600
Total exhaust flow, scfm	16000
Particle counts	ISO 5 = "Class 100" = <100 per ft^3 ISO 6 = "Class 1000" = <1000 per ft^3 2 fixed particle counters with remote telemetry and trending
<u>DI water</u>	
RO quality	dissolved solids reduction by > 96% Bacteria reduction by > 99% Particulate removal down to 5 µm in size
RO capacity, gallons/day	> 4400
RO storage capacity, gal	500
DI Resistivity, Ω-cm	18 x 10^6, with remote telemetry and logging
DI loop flow, gpm	25, with duplex alternating distribution pumps
DI loop delivery pressure	90 psi at pump discharge
Final filter	0.2 µm, stainless steel housing
Resistivity Monitors	supply and return, temperature compensated
DI piping material	PVDF
<u>Process chilled water</u>	
Max. flow, gpm	60
Max. heat load, BTU/h	180000
Supply Temperature	< 60 F, or just above dew point; adjustable, telemetered, and trended.
Δ Pressure	adjustable, 10 psi minimum

Compressed dry air	80-100 psig, from building supply, dual lead-lag source
House nitrogen	approx 60 psig from liquid boiloff
House vacuum	min. 21” Hg, dual lead-lag pumps

Organization Chart



1.0 Requirements for qualification

Users needing to use the cleanroom that have never been previously qualified for the Yale cleanroom will be required to:

1. Obtain the approval of the principal investigator / faculty member who has agreed to be financially responsible for the user's cleanroom usage.
2. Complete the application form, available at: (URL location)
3. Complete the following Yale online training courses:
    a. OEHS online chemical safety training, located at http://info.med.yale.edu/chemsafe
    b. OEHS online hazardous chemical waste training, at http://info.med.yale.edu/chemhaz
    c. Yale Fire Marshal's online Fire Extinguisher training, at http://learn.yale.edu/firetraining
4. Meet with the CR manager, explain your reasons for using clean room and discuss your requirements.
5. Attend an in-house orientation provided by cleanroom staff, to cover the following topics:
    a. Mechanics of cleanroom entry/exit: gowning, card access
    b. Characteristics of CR areas, air pressure, particle count
    c. Process bays, service bays, identification and protocols
6. Classroom and lab training for safety and chemical handling.
    PPE requirements
    Emergency response protocols
    Chemical handling
    Proper use of each of the chemical process benches and hotplates
7. Introduction to Coral
    Using remote Coral
    How to schedule equipment
    How to know status of equipment

8. Pass a written exam. The exam will cover items from (5) through (7) above. The exam will be administered after the completion of the previous items. The exam will be graded by the cleanroom staff. Those not passing the exam will be allowed sufficient time to review the appropriate materials (this Handbook, video recordings, online course work, etc) before retaking the exam.

9. Attend and participate in a cleanroom walkthrough by a cleanroom staff member. The items to be demonstrated will include (at a minimum):
    - Prox card entry and exit protocol
    - Proper gowning / degowning
    - Location of safety equipment, PPE, and supplies
    - Location of spill kits and first aid
    - Location of supplies and chemicals
    - Location of ringdown phones and alarms
    - Proper hazardous waste labeling
    - Coral scheduling and equipment enabling

10. Additional individual one on one training is required to qualify for approval to use process tools and systems, please see a staff member to schedule training.
11. Anyone who has previously been qualified for access to the cleanroom and has less than 30 hours of active cleanroom time per 12 month period, will need the approval of the cleanroom manager, and review process equipment and procedures with a staff member, in order to maintain active status.

2.0 Cleanroom Training

2.1 Intro to cleanrooms

A Basic Introduction to Clean Rooms

By Roger McFadden
Technical Director, Coastwide Laboratories

(source:http://www.coastwidelabs.com/Technical Articles/Cleaning the Cleanroom.htm, 7/2007. Reproduced in part)

A cleanroom is a controlled environment where products are manufactured. It is a room in which the concentration of airborne particles is controlled to specified limits. Eliminating sub-micron airborne contamination is really a process of control. These contaminants are generated by people, process, facilities and equipment. They must be continually removed from the air. The level to which these particles need to be removed depends upon the standards required. The most frequently used standard is the Federal Standard 209E. The 209E is a document that establishes standard classes of air cleanliness for airborne particulate levels in cleanrooms and clean zones. Strict rules and procedures are followed to prevent contamination of the product.

The only way to control contamination is to control the total environment. Air flow rates and direction, pressurization, temperature, humidity and specialized filtration all need to be tightly controlled. And the sources of these particles need to controlled or eliminated whenever possible. There is more to a clean room than air filters. Cleanrooms are planned and manufactured using strict protocol and methods. They are frequently found in electronics, pharmaceutical, biopharmaceutical, medical device industries and other critical manufacturing environments.

It only takes a quick monitor of the air in a cleanroom compared to a typical office building to see the difference. Typical office building air contains from 500,000 to 1,000,000 particles (0.5 microns or larger) per cubic foot of air. A Class 100 cleanroom is designed to never allow more

than 100 particles (0.5 microns or larger) per cubic foot of air. Class 1000 and Class 10,000 cleanrooms are designed to limit particles to 1000 and 10,000 respectively.

A human hair is about 75-100 microns in diameter. A particle 200 times smaller (0.5 micron) than the human hair can cause major disaster in a cleanroom. Contamination can lead to expensive downtime and increased production costs. In fact, the billion dollar NASA Hubble Space Telescope was damaged and did not perform as designed because of a particle smaller than 0.5 microns.

Once a cleanroom is built it must be maintained and cleaned to the same high standards. This handbook has been prepared to give professional cleaning staff information about how to clean the cleanroom.

What is Contamination?

Contamination is a process or act that causes materials or surfaces to be soiled with contaminating substances. There are two broad categories of surface contaminants: film type and particulates. These contaminants can produce a “killer defect” in a miniature circuit. Film contaminants of only 10 nm (nanometers) can drastically reduce coating adhesion on a wafer or chip. It is widely accepted that particles of 0.5 microns or larger are the target. However, some industries are now targeting smaller particles.

A partial list of contaminants is found below. Any of these can be the source for killing a circuit. Preventing these contaminants from entering the cleanroom environment is the objective. It requires a commitment by everyone entering the cleanroom to make it happen. Professional cleaning personnel need to be aware of the importance of controlling contaminants. Strict procedures should be followed whenever entering or cleaning a cleanroom. Compromise is not acceptable when cleaning in a cleanroom.

Sources of Contamination

This is a partial list of some of the commonly known contaminants that can cause problems in some cleanroom environments. It has been found that many of these contaminants are generated from five basic sources. The facilities, people, tools, fluids and the product being manufactured can all contribute to contamination. Review this list to gain a better understanding of where contamination originates.

1. Facilities

Walls, floors and ceilings
Paint and coatings
Construction material (sheet rock, saw dust etc.)
Air conditioning debris
Room air and vapors
Spills and leaks

2. People

Skin flakes and oil
Cosmetics and perfume
Spittle
Clothing debris (lint, fibers etc.)
Hair

3. Tool Generated

Friction and wear particles
Lubricants and emissions
Vibrations
Brooms, mops and dusters

4. Fluids

Particulates floating in air
Bacteria, organics and moisture
Floor finishes or coatings
Cleaning chemicals
Plasticizers (outgasses)
Deionized water

5. Product generated

Silicon chips
Quartz flakes
Cleanroom debris
Aluminum particles

Key Elements of Contamination Control

We will look at several areas of concern to get a better idea of the overall picture of contamination control. These are the things that need to be considered when providing an effective contamination control program.

HEPA (High Efficiency Particulate Air Filter) - These filters are extremely important for maintaining contamination control. They filter particles as small as 0.3 microns with a 99.97% minimum particle-collective efficiency.

CLEANROOM ARCHITECTURE - Cleanrooms are designed to achieve and maintain an airflow in which essentially the entire body of air within a confined area moves with uniform velocity along parellel flow lines. This air flow is called laminar flow. The more restriction of air flow the more turbulence. Turbulence can cause particle movement.

FILTRATION - In addition to the HEPA filters commonly used in cleanrooms, there are a number of other filtration mechanisms used to remove particles from gases and liquids. These filters are essential for providing effective contamination control.

CLEANING - Cleaning is an essential element of contamination control. Decisions need to made about the details of cleanroom maintenance and cleaning. Applications and procedures need to be written and agreed upon by cleanroom management and contractors (if used). There are many problems associated with cleaning. Managers need to answer the following questions before proceeding with any cleanroom cleaning program:

1. What is clean?
2. How is clean measured?
3. What cleaning materials can be used in the cleanroom?
4. When can the cleanroom be cleaned?
5. How frequent does it need to be cleaned?

CLEANROOM GARMENTS - The requirements for cleanroom garments will vary from location to location. It is important to know the local garment requirements of the cleanroom management. Gloves, face masks and head covers are standard in nearly every cleanroom environment. Smocks are being used more and more. Jump suits are required in very clean environments.

HUMANS IN CLEANROOMS - There are both physical and psychological concerns when humans are present in cleanrooms. Physical behavior like fast motion and horseplay can increase contamination. Psychological concerns like room temperature, humidity, claustrophobia, odors and workplace attitude are important. Below are several ways people produce contamination:

1. **Body Regenerative Processes**-- Skin flakes, oils, perspiration and hair.
2. **Behavior**-- Rate of movement, sneezing and coughing.
3. **Attitude**-- Work habits and communciation between workers.

People are a major source of contamination in the cleanroom. Look at the people activities listed below. Notice the number of particles produced per minute during these activities.

PEOPLE ACTIVITY	**PARTICLES/MINUTE (0.3 microns and larger)**
Motionless (Standing or Seated)	100,000
Walking about 2 mph	5,000,000
Walking about 3.5 mph	7,000,000
Walking about 5 mph	10,000,000
Horseplay	100,000,000

COMMODITIES - Care is taken when selecting and using commodity items in cleanrooms. Wipers, cleanroom paper and pens and other supplies that service the cleanroom should be carefully screened and selected. Review of the local cleanroom requirements for approving and taking these items into the cleanroom are essential. In fact, many cleanroom managers will have approval lists of these types of items.

COSMETICS - Many cosmetics contain sodium, magnesium, silicon, calcium, potassium or iron. These chemicals can create damaging particles. Cleanroom managers may ban or restrict cosmetics in the cleanroom. This is usually dependent upon the threat to the product being made in the cleanroom. A recent mirror on a space telescope was fogged up from the cologne that was present in the cleanroom.

MEASUREMENT AND INSTRUMENTATION - Some important measurements related to contamination control are particle count, air flow & velocity, humidity, temperature and surface cleanliness. Cleanroom managers usually have specific standards and/or instruments to measure these factors.

ELECTROSTATIC DISCHARGE (ESD) - When two surfaces rub together an electrical charge can be created. Moving air creates a charge. People touching surfaces or walking across the floor can create a triboelectric charge. Special care is taken to use ESD protective materials to prevent damage from ESD. Cleaning managers should work with their personnel to understand where these conditions may be present and how to prevent them.

General Cleanroom Regulations

Below is a list of general regulations recommended as a minimum for the successful operation of a cleanroom. All professional cleaning personnel should be aware and follow these regulations at all times.

1. All personal items such as keys, watches, rings, matches, lighters and cigarettes should be stored in the personal locker outside the gowning room.

2. Valuable personal Items such as wallets may be permitted in the cleanroom provided they are NEVER removed from beneath the cleanroom garments.

3. NO eating, smoking or gum chewing allowed inside the cleanroom.

4. Only garments approved for the cleanroom should be worn when entering.

5. NO cosmetics shall be worn in the cleanrooms. This includes: rouge, lipstick, eye shadow, eyebrow pencil, mascara, eye liner, false eye lashes, fingernail polish, hair spray, mousse, or the heavy use of aerosols, after shaves and perfumes.

6. Only approved cleanroom paper shall be allowed in the cleanroom.

7. Approved ball point pens shall be the only writing tool used.

8. Use of paper or fabric towels is prohibited. Use of hand dryers equipped with HEPA filters is suggested.

9. Gloves or finger cots should not be allowed to touch any item or surface that has not been thoroughly cleaned.

10. Only approved gloves, finger cots (powder-free), pliers, tweezers should be used to
handle product. Finger prints can be a major source of contamination on some products.

11. Solvent contact with the bare skin should be avoided. They can remove skin oils and increase skin flaking.

12. Approved skin lotions or lanolin based soaps are sometimes allowed. These can reduce skin flaking.

13. All tools, containers and fixtures used in the cleaning process should be cleaned to the same degree as the cleanroom surfaces. All of these items are a source of contamination.

14. NO tool should be allowed to rest on the surface of a bench or table. It should be place on a cleanroom wiper.

15. Only cleanroom approved wipers are allowed to be used. The wipers must be approved for the Class of cleanroom being cleaned.

16. ALL equipment, materials and containers introduced into a sterile facility must be subjected to stringent sterilization prior to entrance.

17. NO ONE who is physically ill, especially with respiratory or stomach disorders, may enter a sterile room. This is a good practice in any cleanroom environment.

Personal Actions Prohibited in Cleanrooms

1. Fast motions such as running, walking fast or horseplay.
2. Sitting or leaning on equipment or work surfaces.
3. Writing on equipment or garments.
4. Removal of items from beneath the cleanroom garments.
5. Wearing the cleanroom garment outside the cleanroom.
6. Wearing torn or soiled garments.

2.2 Orientation Walkthrough

Minimal List of Items to be Covered during an initial Cleanroom Walkthrough

1. Cleanroom entry and exit protocols
2. ISO5 and ISO6 areas
3. service bays, process bays
4. differential pressures between areas
5. particle counters
6. fire extinguishers
7. eyewashes and safety showers
8. ringdown/emergency phones
9. emergency gas off buttons
10. hazardous gas alarm lights, detectors, and status panel
11. wet process benches – location, purpose
12. doors – entry, emergency exit, service bay, sliding

2.3 SEAS CR Personal Contamination Control

1. Entry

Before entering the cleanroom, ensure that you have: eye protection [see section 6.0 , “PPE”], and that you are suitably attired (long pants/trousers, full-coverage shoes, no sandals/flip-flops, no high heels). Be sure to leave your MP3/iPod players in your office as well – they are inappropriate for work in the cleanroom, where paying attention to your environment is important for your safety and the safety of others.

Enter the cleanroom using your Yale ID Proxcard. The door will swing open for you, once your card has authenticated you. If you are entering while other people are entering or leaving, be sure to prox your card (you’ll hear the card reader beep) even if the door is already open, as this “logs” you in to the cleanroom.

The first thing you’ll do is walk over a tacky mat. If the mat is getting dirty, don’t hesitate to pull up the next sheet.

If you are bringing in an item to place in the passthrough: You will find a supply of lab wipes, and a spray bottle of IPA on the rack near the passthrough. Use the spray and the wipes to clean the item before placing it in the passthrough. At this point, think about your cell phone – if you are going to need it in the cleanroom, wipe it down and place it in the passthrough. Once you are gowned up, you won’t be able to pull it out of your pocket if it rings.

Notice the oval-shaped knob next to the passthrough door. This knob operates the door interlock. Turn it counterclockwise to allow “your” door to open. When you close the door, turn the knob clockwise – this now allows the door on the cleanroom side to operate. You will find a similar knob on the cleanroom side, and it has the same function.

Next, before donning the blue shoe covers, make use of the shoe cleaner, located near the entry door. Use it to remove the dirt on your shoes, and then pull the shoe covers over your shoes.

Now put on a pair of vinyl gloves. You will wear these while gowning. Also put on the bouffant hair cover, tucking your hair underneath if

appropriate. If you have a beard or moustache (more than two days growth for most men), also put on a beard cover.

If you do not already have a gown and a hood hanging up in the gowning room, choose one of each now, of the appropriate size, from the rack. Sizes are labeled, and range from small on the left to 3XL on the right (small to XL for hoods).

Now you're ready to step through the door to the gowning room, and onto the next tacky mat. If it's getting dirty, please pull up the next sheet. (Clearly, if the shoe cleaner and the shoe covers are doing their job, it will take a while for this mat to get dirty!)

We gown up in "top-down" fashion. First put on the hood, ensuring the snaps face outward. Tuck in your hair. Fasten the hood closure, and adjust the fit snaps as needed. A full-length mirror is available in the gowning room to help you make sure you have the hood on right, all your hair is tucked in properly, etc.

Next, step into the coverall, while preventing the coverall from contacting the floor as much as possible. This takes some practice to do well. Fasten the coverall with the front zipper, ensuring the hood tails are completely tucked in to the neck of the coverall. Use the full-length mirror to verify that you are "tucked in" completely.

Finally, put on the boots over your blue shoe covers. Use the adjustable strap to secure the lower part of the boot against your foot and shoe. Tuck the coverall into the top part of the boot, fasten the top of the boot to the bottom of the coverall with the snaps provided, and secure the top strap snugly with its snap.

Select the appropriate glove for your intended activity in the cleanroom. The blue nitrile gloves are appropriate for most chemical work. The vinyl gloves, for some, are more comfortable and allow a bit more tactile feedback, but are not appropriate for any chemical work.

Finally, recheck your gowning in the full-length mirror. If you notice anything amiss, fix it now before stepping onto the last tacky mat and into the cleanroom.

2. Exit

The degowning procedure is essentially the reverse of the gowning procedure. While still gloved, remove your garments in “bottom-up” fashion – remove the boots, then the coverall (again being careful to not let it contact the floor). Hang up the coverall on your hangar. You can now snap your boots to the bottoms of the coverall legs to keep all your garments together. Finally, remove the hood, and snap it to the coverall as well.

Next, step out into the entryway and retrieve your possessions from the passthrough (remembering to unlock/lock the door interlock as before). Finally, remove and dispose of the blue shoe covers, your vinyl gloves, and your hair and beard cover.

To operate the hallway door, prox your ID card on the pad adjacent to the door. The door will operate automatically. This also “logs” you out of the cleanroom.

2.4 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*. Develops 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 even 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. Please see a staff member if you need to use the process tanks.

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.

2.5 Process Bench and Fume Hood Protocols

Tool 204A "Photoresist Spin/Bake Bench"

Chemicals allowed:

Clearly marked on bench sign posted on bench

Resist dispense protocol:

- Resist / LOR will be dispensed using a disposable plastic pipette.
- The pipette will be used to draw a quantity of resist from a room-temperature "aliquot" bottle of resist, NOT from the quart or gallon "mother" bottle!
- Pipettes will not be reused – once the dispense and spin are completed, the pipette will be disposed of in a Ziploc baggie, which will then be placed in the cleanroom trash.
- The "aliquot" bottle will be refilled from the "mother" bottle ONLY after the mother bottle is allowed to come to room temperature, thus avoiding the introduction of water vapor from the room air. After being used to refill the aliquot, the mother bottle can be tightly recapped and returned to the refrigerator.

Spinner cleaning procedure:

- For AZ-type resists, the cleaning solvent of choice is Microchem EBR, **DO NOT SQUIRT ACETONE INTO THE LAUREL SPINNERS**, internal components are not compatible with acetone and will damage the spinner. For LOR resist, NMP seems to do a better job.
- Place a 3" dummy silicon wafer, properly centered, on the spinner chuck. Switch on the vacuum, and close the lid. Program the spinner to use a speed of 1000 rpm for two minutes (120 seconds). Start the spinner. While the wafer is spinning, use the squirt bottle to spray the solvent of choice onto the center of the wafer, through the hole in the lid of the spinner. Do this for about 15 seconds, then pause, then again for about 15 seconds. If the appearance of the spinner bowl suggests that more cleaning is required, continue to spray for another 15 to 30 seconds. Now stop the spinner, open the lid, take out the dummy wafer, and use a lab wiper to wipe off all of the interior surfaces of the spinner. Dispose of the wipers in a manner similar to the plastic pipette – place them in a Ziploc baggie before disposing of them in the trash.
- Leave the spinner cleaner than you found it!

Hot plate protocol:

- Hot plates in this process bench are for **wafers and samples only** – no beakers, etc.
- Set the hot plate temperature(s) to the desired value(s) before spinning your sample.
- The 6" precision hot plate has a vacuum holddown feature to ensure intimate thermal contact with the sample, and is best used with whole wafers as opposed to small fragments. It is **essential** that the back of the wafer be clean and free of any resist residue! Use your tweezers and inspect the back of your sample before placing it on this hot plate. If it's not clean, don't bake it – strip it and recoat.
- Failure of the exhaust to the bench will disable the hot plates, as well as the resist spinners.

Tool 103 "Resist Spin/Bake Bench"

Chemicals allowed:

Clearly marked on bench sign posted on bench

Resist dispense protocol:

- Resist / LOR will be dispensed using a disposable plastic pipette.
- The pipette will be used to draw a quantity of resist from a room-temperature "aliquot" bottle of resist, NOT from the quart or gallon "mother" bottle!
- Pipettes will not be reused – once the dispense and spin are completed, the pipette will be disposed of in a Ziploc baggie, which will then be placed in the cleanroom trash.
- The "aliquot" bottle will be refilled from the "mother" bottle ONLY after the mother bottle is allowed to come to room temperature, thus avoiding the introduction of water vapor from the room air. After being used to refill the aliquot, the mother bottle can be tightly recapped and returned to the refrigerator.

Spinner cleaning procedure:

- For AZ-type resists, the cleaning solvent of choice is Microchem EBR, **DO NOT SQUIRT ACETONE INTO THE LAUREL SPINNERS**, internal components are not compatible with acetone and will damage the spinner. For LOR resist, NMP seems to do a better job.
- For most electron resists (PMMA/PMAA), acetone is probably the most effective.
- Place a 3" dummy silicon wafer, properly centered, on the spinner chuck. Switch on the vacuum, and close the lid. Program the spinner

- ***Leave the spinner cleaner than you found it!***

Heated Ultrasonic process tank usage:

- Tank heater and ultrasonic generator are disabled until/unless the fluid level is high enough to raise the twin floats at the back of the tank.
- The tank is filled manually, and is drained into a built-in waste tank.
- The ultrasonic generator switch and the tank heater switch and temperature control are in the process bench head case. DO NOT HEAT ANY FLUID ABOVE ITS FLASH POINT in this tank. NMP = 95˚ C, acetone = -20˚ C, methanol = 12˚ C.
- The tank drain is disabled if the fluid temperature is above a setpoint, currently believed to be around 65˚ C.
- Failure of the exhaust to the bench will disable the tank heater and the ultrasonic generator.
- The process tank has a stainless cover. When the tank is not in use, the cover provides more worktop area.

Hot plate protocol:

- See description under tool 204A, above.
- Failure of the exhaust to the bench will disable the hot plates, as well as the resist spinners, in this bench.

Tool 103A "Soft Litho/MEMS Spin/Bake Bench"

Chemicals allowed:

Clearly marked on bench sign posted on bench

Resist dispense protocol:

- SU-8 and PDMS are generally too viscous for the disposable pipettes. Other dispense methods will have to be employed.

- See comments below regarding the preparation of the spinner inside surfaces.

Spinner cleaning procedure:

- **It is ESSENTIAL that the spinner be cleaned immediately after use, as the materials used in this tool are known to harden up in a short period of time, and will surely foul the spinner, necessitating downtime and potentially expensive repairs.**
- It is traditional to protect the inside of the spinner with filter paper, lab wipes, or aluminum foil prior to spinning. This has the disadvantage that it is messy to clean up and dispose of the trash. The advantage is that it does help prevent contact of the fluid with the spinner inner surfaces. Until/unless we come up with a better cleaning method, this might be the only viable option for this spinner. In any case, dispose of the spinner trash properly, in a plastic Ziploc bag, to reduce odor problems.
- ***Leave the spinner Cleaner than you found it!***

Heated Ultrasonic process tank usage:

- See description under Tool 103
- Failure of the exhaust to the bench will disable the tank heater and the ultrasonic generator.

Hot plate protocol:

- Hot plates in this process bench are for **wafers and samples only** – no beakers, etc.
- Set the hot plate temperature(s) to the desired value(s) before spinning your sample.
- Ensure the back of your sample is clean and devoid of spun material before baking. Failure to do so may result in (1) soiling of the top of the hot plate, and/or (2) destructive adhesion of your sample permanently to the hot plate.
- Failure of the exhaust to the bench will disable the hot plates, as well as the resist spinners.

Tool 106 "Solvent Hood"

Chemicals allowed:

Clearly marked on bench sign posted on bench

Heated ultrasonic tank usage:

- See description under Tool 103, above. Be advised, however: this hood has a second "phantom" tank opening in the worktop, but there is no tank beneath the cover – it's just an opening to the plenum below.
- Failure of the exhaust to the bench will disable the tank heater as well as the ultrasonic generator.
- The process tank has a stainless cover. When the tank is not in use, the cover provides more worktop area.

Hot plate usage:

- This hood is equipped with one explosion-proof hot plate, and one explosion-proof stirring hot plate. These two hotplates are intended for heating beakers, not for baking wafers.
- "Explosion-proof" simply means the hot plate does not contain any ignition sources, like thermostat contacts. It does **not** mean that the fluid you are heating will not catch fire! Do not heat any fluid above its flash point temperature with these hot plates (or any other hot plates, for that matter). See the MSDS to verify flash points.
- These hot plates do not have temperature readouts. Use an immersion thermometer to monitor the temperature of the fluid you are heating. **Do not** "walk away" from a beaker of fluid being heated on a hot plate in this hood!
- Failure of the exhaust to the bench will disable the hot plates.

Tool 104 "Acid Hood"

Chemicals allowed:

Mineral Acids (sulfuric, hydrochloric, nitric, phosphoric)
Acetic Acid and mixtures
HF, BHF
DI water
Bromine
Other acid mixtures (etches, etc)

Hot plate usage:

- This hood is equipped with one ceramic-top hot plate, and one ceramic-top stirring hot plate. These two hotplates are intended for heating beakers, not for baking wafers.
- Failure of the exhaust to the bench will disable the hot plates.

Heated process tank protocol:

- The tank heater is disabled if the level of fluid in the tank is below approx. 60% full.
- The heater controls are located on the headcase: a switch for enabling the tank heater, and a temperature controller for setting the desired tank temperature.
- Samples may be placed in the process tank using single-wafer dipsticks, or cassettes, or other suitable holders. Simply placing a wafer or other sample in the tank without some sort of holder is probably a bad idea – "fishing" the sample out of the tank after it has been processed will be problematic at best, and most likely hazardous.
- The protocol for emptying the tank, and the built-in waste tank, is similar to that described for Tool 103, above. Interlocks are provided to prevent emptying a tank before it has been allowed to cool. It is still vitally important that the waste tank be emptied, and the process tank rinsed down with DI, prior to leaving the hood!
- This tank and the unheated process tank (see below) share the same waste tank. Do not empty the process tank unless you know the waste tank to be empty, to avoid unwanted chemical reactions in the waste tank.
- Do not use the heated process tank with HF-containing mixtures.
- Failure of the exhaust to the bench will disable the tank heater.
- The heated process tank has a plastic cover. When the tank is not in use, the cover provides more worktop area.

DI overflow rinse tank protocol:

- Samples may be placed in the overflow tank using single-wafer dipsticks, or cassettes, or other suitable holders, for final DI rinsing. Simply placing a wafer or other sample in the overflow tank without some sort of holder is probably a bad idea – "fishing" the sample out of the tank after it has rinsed will be problematic.
- The controls for the overflow tank are located in the headcase – a switch to start or stop the flow of DI into the tank, and a timer which will automatically stop the rinse process after the timer expires.
- The resistivity of the overflow tank effluent can be monitored with the resistivity meter in the headcase. The meter has a two-position selector switch: one position monitors the incoming DI water to the hood; the other position monitors the tank effluent.

- The overflow tank drains to the plenum, and not to the internal waste tank, therefore no other fluids are allowed in the rinse tank – only DI water is allowed.
- The overflow rinse tank has a plastic cover. When the tank is not in use, the cover provides more worktop area.

Tool 105 "Base Hood"

Chemicals allowed:

Ammonium hydroxide and mixtures
Tetra-methyl ammonium hydroxide (TMAH) and mixtures
Aqueous alkaline resist developers
DI water
Other aqueous alkaline mixtures and etches

Hot plate usage:

- See protocol listed above for Tool 104, Acid Hood.

Heated process tank protocol:

- See protocol listed above for Tool 104, Acid Hood, but substitute "alkaline" for "acid".

Unheated process tank protocol:

- Same as for the heated tank, described above, with the following comment:
- Both the heated and the unheated tank will drain into the same built-in waste tank. It is important, when using both tanks, to drain and rinse out one of the tanks (thereby emptying and rinsing the waste tank) before emptying the other process tank.

DI overflow rinse tank protocol:

- See protocol listed above for Tool 104, Acid Hood

Tool 107 "CMOS Processing Hood"

Chemicals allowed:

Clearly marked on bench sign posted on bench

Hood usage restriction:

This hood is to be used only for CMOS-clean sample preparation and cleaning operations – no heavy metals, no metal-ion-bearing reagents. This tool in unique among the wet chemistry tools in the cleanroom, in that it has its own HEPA-filtered air supply above the worktop.

Hot plate usage:

- This hood is equipped with one ceramic-top hot plate, and one ceramic-top stirring hot plate. These two hotplates are intended for heating beakers, not for baking wafers.
- Failure of the exhaust to the bench will disable the hot plates.

Unheated process tank usage:

- Samples may be placed in the process tanks using single-wafer dipsticks, or cassettes, or other suitable holders. Simply placing a wafer or other sample in the tank without some sort of holder is probably a bad idea – “fishing” the sample out of the tank after it has been processed will be problematic at best, and most likely hazardous.
- The protocol for emptying the tanks, and the built-in waste tank, is similar to that described for Tool 103, above. It is still vitally important that the waste tank be emptied, and the process tank rinsed down with DI, prior to leaving the hood!
- The two process tanks have plastic covers. When the tanks are not in use, the cover provides more worktop area.

DI overflow rinse tank usage:

- See description above for Tool 104, Acid Hood

2.6 CORAL

(Material in this chapter is taken largely from the “OpenCoral Introduction and Overview” found at http://www.opencoral.org)

Welcome to OpenCoral. The OpenCoral Software System is a suite of software tools that is designed to help with the management and operation of advanced laboratories such as micro- and nano-fabrication facilities found in a number of universities.

What is OpenCoral?

For the user in the lab, it includes the following key capabilities:

- Allows equipment to be reserved in advance and to see who else has equipment reserved.
- Allows equipment to be enabled and disabled when in use to indicate to others that the equipment is in use.
- Report equipment problems and serious shutdown conditions.
- Quickly check on the operational status of each piece of equipment and examine more detailed reports of problem/shutdown conditions and their resolution.
- Allow checkout of laboratory supplies such as wafers, mask blanks, and storage containers.
- Optionally, collect and save run data during processing.

For the lab management and staff, it includes the following key capabilities:

- Maintain lists of qualified users on each piece of equipment.
- Establish accounts, add equipment, add new users, change passwords
- Allow certain users to have special privileges on specific pieces of equipment. For example:
    - An "operator" is allowed to charge others for equipment or staff time spent on their behalf.
    - An "instructor" is allowed to qualify other people to use that piece of equipment.
    - A "maintainer" is allowed to clear equipment problem and shutdown conditions.
    - An "engineer" is allowed to do all of the above.
- Generate detailed laboratory usage information including equipment reservations, equipment usage, staff and training

activities, and equipment problems and shutdown condition for use in generating laboratory charges and helping to manage the facility.
- Specify which projects each lab member is allowed to work on and, in turn, specify which account each project is allowed to charge to.
- Subscription to monthly charged services such as storage locker facilities, monthly cardkey access charges, etc.
- Optionally interlock equipment so that it must be enabled in order to function properly.

Because each facility is unique and likely has special needs, Coral is designed to be as flexible as possible and allows for many configurable capabilities. The range of features to support facility-specific flexibility includes:

- Examples of policies related to equipment reservations include:
    - Only qualified users can reserve equipment.
    - Non-staff members may only reserve equipment 10 days in advance
    - Users can only reserve a maximum of 10 hours on this popular machine.
    - Users can only reserve a maximum of 2 hours of time on a specific piece of equipment during "prime time" (e.g., 8 a.m. to 6 p.m. on Monday-Friday)

Starting a Remote Coral client at Yale

- Ensure you have a Coral account on the lab server. This should happen automatically once you are qualified to use the cleanroom.
- From a computer with a University IP number, point a browser to:
  http://uelmserver.eng.yale.edu/remotecoral
- Click on the "Remote OpenCoral" link. If you already have the Java runtime installed, it should eventually bring up a window that says "Coral Login Dialog". (On the way, it will ask you something about a "bouncy castle" and whether to trust it. The answer is "yes", even though this is an odd name.) If this login window does not come up, you might need to install the Java runtime environment (JRE). The other link on the web page above, takes you to the Sun website for this purpose. You want Downloads -> Java SE -> JRE 6. Accept the license agreement,

choose the download for your platform, download and install as an administrator.

- Your login name is your Yale NetID. Initially your remote Coral password is the same as your NetID. You may want to change this of course, but you can't change it unless you run a “local” Coral on a PC in the cleanroom, for security reasons. See a staff member to change your password.
- Once Coral opens, you will, on the left side of the window, see a hierarchy of objects with "Center for Microelectronic Materials and Structures" at the top, followed by “cleanroom”. The various categories and pieces of equipment are listed below “cleanroom”. To see the reservation, history, policy, and maintenance entries for a piece of equipment, select (click on) the item, then navigate with the tabs on the right side of the screen.
- Equipment currently in use will be listed with the NetID of the user after the equipment name, in parentheses. Equipment that *you* are qualified for will be listed with a star (*) to the right of the equipment name. You can make and delete reservations for such equipment, subject to that equipment’s reservation policies: after selecting the equipment, click on “Reservation Actions -> Make”. To delete a reservation, click on your reservation *in the reservation time-and-date table,* then click on “Reservation Actions -> Delete”.
- To use a piece of equipment, it must first be *enabled* on Coral. To enable, select the equipment as described above, then click on “Equipment Actions -> Enable”. Once you have finished with the item, it must be *disabled* using “Equipment Actions -> Disable”.
- To make a comment about, or report a problem with, a piece of equipment, click on the equipment name, and then click on “Equipment Actions -> Report Problem” or “Make Comment”. Equipment with one or more unresolved problems reported appears in the hierarchy with a *yellow* “traffic light” beside it. Equipment in shutdown status will appear with a *red* traffic light, and equipment in that status cannot be enabled. Equipment *comments* do not affect the status of the traffic light. Users are encouraged to make use of the comment and problem reporting facilities in Coral, as they provide useful information for the timely maintenance and repair of our equipment.

<u>Other notes</u>

- You can start a Remote Coral from any browser on the Internet by first connecting through the Yale VPN - this makes you

http://www.yale.edu/its/network/vpn.html for details.

2.7 Miscellaneous

Cleanroom Cordless Phone/Intercom System

This system consists of a base unit and handset and 6 additional handsets throughout the cleanroom complex. These are 5.8 GHz. phones, so range and interference should not be an issue in the vicinity of the cleanroom.

Base unit phone number: 432-4307

Handset #	Location
1	Base unit, metrology bay (front section of cleanroom)
2	Lithography bay
3	Plasma bay
4	Entry
5	Room 528 (equipment/gas room)
6	Jim Agresta's office (529)
7	Mike and Chris's office (527)

Intercom feature:

Press **int'com** button
Select handset you wish to contact
Press **Talk** (green phone icon) to answer

DirectLink feature- allows you to use two phones as a two way radio
Both handsets must be in DirectLink mode

Press **menu soft key**
Select **OK**, follow directions press enter
Phone now in DirectLink mode, to call another handset
Press **DirectLink** soft key
Select handset to communicate with
If other handset not in DirectLink mode, display will show **Out of Range**
To receive call press **Answer** soft key or **Talk**

Some stored numbers

A few numbers are stored in the collective system (please don't add personal numbers, these phones will occasionally be purged)

With phone in typical standby mode (as it sits in the charger)
Press 4 way button to left (book icon)
Press down to scroll through the phonebook

SEAS CLEAN ROOM POLICY AND PROCEDURES
Rev. Oct.-2009-1

The following procedures and polices 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

5.8.2 SEAS Policies

5.1. User Fees and Costs

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

5.1.2. 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.

5.2. Time Keeping

5.2.1. 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.

5.2.2. 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.

5.2.3. Random review of surveillance date 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.

5.3. Visitors/Guests

5.3.1. A visitor or guest is defined as anyone who is not a qualified cleanroom user, and has permission to enter the cleanroom with a host for the purposes of observation. If not a member of the Yale community, they must obtain a guest ID from a cleanroom staff member.

5.3.2. A host is defined as a qualified cleanroom user. Anyone wishing to bring a guest into the cleanroom should first notify the cleanroom manager for permission.

5.3.3. The host is responsible for the conduct and safety of their visitor/guest while in the cleanroom.

5.3.4. The visitor/guest is required to swipe in and out of the cleanroom, even if using a guest pass, and sign into the logbook available in the entry.

5.3.5. A visitor/guest may not perform any operations or operate any equipment in the cleanroom.

5.4. External customers

5.4.1. External customers are non Yale researchers who have been approved by the FoE business office, to have met and acknowledged the requirements and agreed to the non academic rate structure of the clean room.

5.5. Precious Metals

5.5.1. Precious metals defined as gold and platinum (as of 6/08)

5.5.2. The cleanroom inventory does not include precious metals, purchase and storage of precious metals for deposition, or other process requirements, will be the responsibility of each research group.

5.6. Clean Room After Hours Policy

5.6.1. Hours of Operation

5.6.1.1. 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.

5.6.2. After Hours

5.6.2.1. 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)*

5.6.3. Protocols for after hours work in the clean room

5.6.3.1. 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.

5.6.3.2. 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.

5.6.3.3. 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.

5.6.3.4. Random audits of after hours logs and surveillance will be conducted to validate safety compliance.

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

5.6.4. Allowed Operations

5.6.6.1.1. Lithography tools: vacuum bake/vapor prime, resist spin/bake, mask alignment/exposure, development, microscope inspection

5.6.4.2. Develop plates using APT plate developer

5.6.4.3. Operate vacuum deposition systems

5.6.4.4. Operate metrology tools: Alpha Step, Ellipsometer, Nanometrics, microscopes

5.6.4.5. TRE and Heidelberg mask makers

5.6.4.6. MCS plasma asher

5.6.4.7. Oxford 80 fluorine RIE/ICP

5.6.4.8. GSI PECVD
5.6.4.9. Solaris RTA
5.6.4.10. CVD furnace
5.6.4.11. Lindberg furnace

5.6.5. 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*.

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

Critical point dryer

Oxford 100 chlorine RIE

5.7 **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

5.7.1 ***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

5.7.2 ***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

5.7.3 ***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.

5.7.4 ***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

5.7.5 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

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.

5.7.6 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

Protocol and equipment Operations Violations

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

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

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

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

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

5.7.7.3 ***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

5.7.7.4 ***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

5.7.8 Response to violations of training and or protocols resulting in *policy violation*, 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

5.7.9 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.

5.8.0 Policy Changes

There will be times that warrant either a change or addition of policies which govern the cleanroom. In order to maintain fairness and careful consideration to safety and protocols:

- Submit proposal to CR manager in charge
- The proposal will be reviewed, it may need to be discussed with OEHS or Technical review committee.
- Any changes or differences will be discussed.
- Final version goes to Dean for approval

5.8.1 Review Committees

Facilitates the cleanroom community (researchers, students) to impart areas of specialty to other researchers and encourages participation in process support.

These committees should be used to review novel process techniques, consider cross contamination issues, make recommendations, etc.

Currently established committees:

Oxford 80 Process Review/Approval Committee

6.0 Safety

6.1.0 PPE

6.1.1 Eyewear

All occupants of the cleanroom are required to wear protective eyewear. Acceptable forms of eyewear include: safety glasses, chemical splash goggles, or prescription glasses **with properly-fitting side shields.** Glasses without side shields are not adequate. Also, contact lenses are not recommended when working with or around chemicals, due to the tendency of chemical vapors to collect behind the contact lens and irritate the cornea.

6.1.1 Gloves

All occupants of the cleanroom will don and wear a pair of gloves, for the protection of hands and fingers as well as the protection of cleanroom surfaces from fingerprints. Vinyl, latex, and nitrile gloves are acceptable for this purpose. Vinyl and nitrile gloves, as well as the heavier utility-grade gloves, are stocked in the cleanroom.

6.1.1 Apron

Chemically-resistant, aprons are available in the wet processing bay, and are to be worn when working with hot and/or strong acids, bases, or HF.

6.2.0 Material Safety Data Sheets (MSDS)

Two binders containing MSDS's for all hazardous materials in the cleanroom will be kept in the gowning room. They are filed alphabetically with A-L in one binder and M-Z in the other.

The binders will be maintained by the cleanroom staff, with sections added when new chemicals or gases are approved and introduced into the cleanroom. Should you not find a datasheet that you think should be in the binders, please contact a staff member.

6.7 Toxic Gas Monitoring System

6.3.1 Status Panel

There are three status panels for the toxic gas monitoring system. One is in the cleanroom entryway, another is in the back of room 529, and the third is on the first floor of the Becton Center, near the Prospect St. entrance. The status panel normally displays the current detected quantity for 16 detection points in the cleanroom, and in the gas cabinets in room 528. If an alarm is raised, these panels can quickly provide information relating to the source of the alarm signal.

6.3.2 Indicator lights and horns

There are several sets of indicator lights for the toxic gas monitoring system. Each set is composed of three lights arranged horizontally: one white, one yellow/orange, and one red. The white light indicates a “low-level” alarm. The yellow/orange light indicates a “mid-level” alarm. The red light indicates a “high-level” alarm. When activated, the lights will “strobe” at a rate of about twice per second.

6.3.3 Actions to take in response to an alarm condition

Low-level “white light” alarm

- If possible, identify likely/known sources of leak and repair immediately.
- If leak cannot be stopped, or users anticipate condition will worsen, leave room and assemble outside in hall (may degown and leave normally)
- Contact Cleanroom Tech staff
- Review events and effect repair if safely possible. If not possible, leave area and hit “Emergency Stop” gas button

Mid-level “yellow/orange light” alarm

- Leave cleanroom, assemble outside in hall (may degown and leave normally)
- Contact Cleanroom Tech staff as well as Yale ER Team (YPD, YFM, OEHS)
- Assemble and review events, plan for safe repair/response
- Do not re-enter cleanroom until alarms clear and staff members indicate it is safe to re-enter

High-level “red light” alarm

- Building fire alarm will sound.
- Leave building, assemble outdoors **(leave cleanroom through nearest door, DO Not stop to degown)**
- Assemble and review events, plan for safe repair/response
- Do not re-enter cleanroom until alarms clear and staff members indicate it is safe to re-enter

The cleanroom is equipped with two emergency gas cabinet shutoff buttons. Activation of these buttons will cause all gas flows from the gas cabinets in 528 to shut off. This includes all of the toxic gases, flammable/pyrophoric gases, and oxidizing gases. As an aside, the gas cabinets will also shut off their output flow if the building fire alarm is activated. The gas cabinets will require a manual reset in order to reestablish the gas flow.

6.7 Chemical spills

- All qualified cleanroom users have been trained in chemical spill response as part of the required on-line chemical safety training. Refer to Section 2.5 of the Yale University Chemical Hygiene Plan for spill cleanup information.
- For all spills, alert people in immediate area and restrict access to spill location.
- Identify the materials involved, quantity, and specific location of the spill. Evaluate hazard(s) and address personal contamination/injury. Summon any additional emergency services needed.
- Only attempt to clean up a chemical spill if you are comfortable and confident that it can be done safely – if in doubt, use one of the ringdown phones to call for help. If the spill has caused the evolution of noxious vapors, leave the area immediately and call for help (785-3555 – OEHS emergency phone number). If possible, cover with absorbent material to reduce vapors before leaving the area.
- Wear basic protective equipment appropriate to hazard to clean small spills – if respiratory protection is needed,

the incident is NOT minor and OEHS should be contacted immediately.

- To clean minor spills, spill kits and neutralizer for acids, bases, and HF are kept in the wet process bay. Use appropriate material to absorb or neutralize spilled material. Work from perimeter inwards. Collect residue, place in heavy plastic bag or other receptacle, affix waste label describing contents, and contact Environmental Services for waste pick-up.
- Clean spill area with soap and water.

6.8 First Aid

- The first aid kit is kept in the gowning room, along with the gowning supplies.
- Minor cuts, scrapes, burns can be treated using the supplies in the first aid kit. Move the victim to the gowning room for treatment if possible and appropriate.
- If there is ANY possibility that the injury is anything beyond minor, or if the victim exhibits ANY symptoms of shock, use the ringdown phone (red button, no dialing required) to call for medical assistance

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6.9. Chemical exposure

Personnel exposure to wet chemicals, particularly caustics, requires immediate action. Eyewashes and safety showers are located in the wet chemistry areas, as well as in the hallway outside the cleanroom. The victim should use the shower or the eyewash for at least 15 minutes to mitigate and dilute the chemical. Those assisting the victim should use the ringdown phone to call for emergency assistance (use the red button, no dialing required).

Hydrofluoric Acid, HF, is highly hazardous and ***can cause severe burns and death if not treated quickly***. All areas where HF is used or stored should have 2.5% calcium gluconate ointment immediately available. In the event of an HF exposure,

1. Immediately remove contaminated clothing under the shower and rinse for 5 minutes.
2. Gently rub calcium gluconate ointment onto the affected area.

3. Continue applying until emergency medical responders arrive. If the gluconate gel is not available, continue rinsing the affected area for a minimum of 15 minutes.
4. Be sure to inform medical responders that the emergency involves HF exposure.

ALL cleanroom injuries, no matter how minor, must be reported to a lab staff member for documentation and, if appropriate, remediation of the hazard that caused the injury.

6.9. Fire

The two double doors from the cleanroom to the hallway are the emergency exits. A fire alarm pull box is located adjacent to each door. An alarm will sound when the door is opened from the inside, so don't be surprised. ***Do not worry about your cleanroom garment when exiting the cleanroom under an emergency condition – you can remove it after you are in a place of safety***.

Should it be needed, a fire blanket is located in a vertical cabinet next to chase 2. It can be used to help douse the flames on a person who has caught fire. To use, pull the blanket out of the cabinet, then roll the person up in the blanket to smother the flames.

All cleanroom users are required to take the on-line Yale Fire Marshal's Fire Extinguisher Training. Fire extinguishers are located at several places in the cleanroom. They are of the "CO_2" type. Before employing an extinguisher, pull a fire alarm box to summon assistance.

Operation of the extinguisher requires four steps:

1, pull the pin.

2, aim at base of flames

3, squeeze the trigger to release the CO_2 vapor

4, sweep the nozzle horizontally back and forth to smother the flames.

The memory key is "P A S S":

Pull, **A**im, **S**queeze, **S**weep.

Only attempt to put out a fire if you have a clear escape path behind you, and you feel comfortable operating the extinguisher.

In the event that the building fire alarm sounds, leave the cleanroom immediately (but in an orderly fashion: Don't Panic) using the emergency exits to the hallway. Do not linger to shut down tools/processes. Do not worry about removing your cleanroom gown until you are in a place of safety. Do not reenter the building until the alarm has been turned off, and the Fire Department has indicated it is safe to reenter.

6.9.1 Ringdown phones

The cleanroom is equipped with three "ringdown boxes": one in the wet process bay, adjacent to the sliding door; one adjacent to the CMOS process bench at the end of the metrology bay; and one at the end of the thermal bay. These boxes function similarly to the blue security boxes we see sprinkled around campus. Depending on how you actuate them, they can serve as a normal campus telephone, or to summon immediate emergency assistance from campus security and/or Yale Police.

To operate as a telephone,

- Press the black button. you will hear a dial tone.
- Now dial the phone number on the touchtone pad. The ringdown box now functions like a speakerphone for the remainder of your conversation.
- To end the call, press the black button again.
- In case of emergency, press the red button. No touch tone pad dialing is required. Yale Security will answer the call, and the box will again function like a speakerphone.

Be advised that Yale Security will know you location when they answer the call (they see "Becton Center, 5th floor, cleanroom"). Please be clear when stating your emergency to the dispatcher, who will then be able to summon the appropriate emergency responder.

7.0 Process Equipment

A: Chemical process benches

Manufacturer: ReynoldsTech, Syracuse NY
http://www.reynoldstech.com

Tool 204A "Photoresist Spin/Bake Bench"

Location: Litho Bay
Purpose: resist spinning and wafer baking
Material: Stainless Steel
Accessories:
- Laurell spinner "Laurell1"
- Headway spinner
- SCS precision hotplate with vacuum holddown
- (2) aluminum-top Barnstead hotplates
- Underdeck explosion-proof refrigerator
- Stand-alone utility timers
- N_2 spray gun
- Exhaust interlock: Sounds audible alarm, and disables hot plates

Tool 103 "Resist Spin/Bake Bench"

Location: Wet process bay
Purpose: resist spin, wafer bake, wafer strip, etc.
Material: stainless steel
Accessories:
- (2) Laurell spinners "Laurell2, Laurell3"
- SCS precision hot plate with vacuum holddown
- (2) aluminum-top Barnstead hot plates
- In-deck heated, ultrasonic tank
- In-deck drain sump with frontside manual drain
- Utility sink with DI gooseneck faucet and point-of-use 0.2 µm filter
- (2) DI deck hoses
- (2) N_2 spray guns
- (4) Stand-alone utility timers
- Exhaust interlock: Sounds audible alarm, and disables all accessory power
- Safety interlocks for tank drain, tank level, ultrasonic generator, etc.

Tool 103A "MEMS / Soft Litho Spin/Bake Bench"

Location: Wet process bay
Purpose: resist spin, wafer bake, wafer strip, etc.
Material: stainless steel
Accessories:
Laurell spinner “Laurell4”
(2) aluminum-top Barnstead hot plates
In-deck heated, ultrasonic tank
In-deck drain sump with frontside manual drain
Utility sink with DI gooseneck faucet and point-of-use 0.2 μm filter
(2) DI deck hoses
(2) N_2 spray guns
(4) Stand-alone utility timers
Exhaust interlock: Sounds audible alarm, and disables all accessory power
Safety interlocks for tank drain, tank level, ultrasonic generator, etc.

Tool 106 “Solvent Hood”

Location: Wet process bay
Purpose: solvent processing
Material: stainless steel
Accessories:
aluminum-top explosion-proof hot plate
aluminum-top explosion-proof stirring hot plate
In-deck heated, ultrasonic tank
In-deck drain sump with frontside manual drain
Utility sink with DI gooseneck faucet and point-of-use 0.2 filter
(2) DI deck hoses
(2) N_2 spray gun
Stand-alone utility timers
Yellow hood light
Exhaust interlock: Sounds audible alarm, and disables all accessory power
Safety interlocks for tank drain, tank level, ultrasonic generator, etc.

Tool 104 “Acid Hood”

Location: Wet process bay
Purpose: acid processing
Material: FM4910-rated CPVC
Accessories:
Ceramic-top hot plate

Ceramic-top stirring hot plate
In-deck heated tank
In-deck DI cascade overflow rinse tank with DI resistivity probe
DI resistivity monitor display
In-deck drain sump with frontside manual drain
Utility sink with DI gooseneck faucet and point-of-use 0.2 filter
(2) DI deck hoses
(2) N_2 spray guns
(4) Stand-alone utility timers
Yellow hood light
Exhaust interlock: Sounds audible alarm, and disables all accessory power
Safety interlocks for tank drain, tank level, etc.

Tool 105 "Base Hood"

Location: Wet process bay
Purpose: caustic/alkaline processing
Material: FM4910-rated CPVC
Accessories:

Ceramic-top hot plate
Ceramic-top stirring hot plate
In-deck heated tank
In-deck DI cascade overflow rinse tank with DI resistivity probe
DI resistivity monitor display
In-deck drain sump with frontside manual drain
Utility sink with DI gooseneck faucet and point-of-use 0.2 filter
(2) DI deck hoses
(2) N_2 spray guns
(4) Stand-alone utility timers
Yellow hood light
Exhaust interlock: Sounds audible alarm, and disables all accessory power
Safety interlocks for tank drain, tank level, etc.

Tool 107 "CMOS Hood"

Location: thermal/plasma bay
Purpose: MOS-clean processing
Material: FM4910-rated CPVC
Accessories:

HEPA fan filter box over entire work space

Ceramic-top hot plate
Ceramic-top stirring hot plate
Benchtop ultrasonic cleaner
(2) In-deck non-heated process tanks
In-deck DI cascade overflow rinse tank with DI resistivity probe
DI resistivity monitor display
In-deck drain sump with frontside manual drain
Utility sink with DI gooseneck faucet and point-of-use 0.2 filter
(2) DI deck hoses
(2) N_2 spray guns
Vacuum wand suitable for 8" wafers
(4) Stand-alone utility timers
White Hood lights
Exhaust interlock: Sounds audible alarm, and disables all accessory power
Storage cupboards below deck
Safety interlocks for tank drain, tank level, etc.

B: Deposition

Name:	**Pete,** Tool ID 01
Type:	e-beam and/or thermal, turbo pumped
Manufacturer:	Kurt Lesker http://www.lesker.com
Materials:	metals: gold, chrome, nickel, titanium, palladium
Name:	**Denton,** Tool ID 02
Type:	e-beam/thermal, cryopumped
Manufacturer:	Denton Vacuum http://www.dentonvacuum.com
Materials:	metals: gold, chrome, nickel
Name:	**Varian,** Tool ID 04
Type:	thermal evaporator, turbopumped
Manufacturer:	Varian http://www.varianinc.com
Materials:	some metals and dielectrics
Name:	**Edwards,** Tool ID 03
Type:	thermal evaporator, cryopumped
Manufacturer:	Edwards High Vacuum http://www.bocedwards.com
Materials:	Aluminum (CMOS-clean restricted use)
Name:	**Lesker,** Tool ID 05

Type:	UHV sputter and thermal dep, cryopumped
Manufacturer:	Kurt Lesker http://www.lesker.com
Materials:	Niobium and other superconductor-specific materials

C. Plasma

Name:	**Oxford80,** Tool ID 101
Type:	RIE/ICP Etcher "PlasmaLab 80Plus"
Manufacturer:	Oxford Instruments http://www.oxford-instruments.com
Etch Chemistries:	Fluorine-based halocarbons, SF6, O2, restricted use

Name:	**Oxford100,** Tool ID 212
Type:	RIE/ICP Etcher (Loadlocked) "PlasmaLab System 100"
Manufacturer:	Oxford Instruments http://www.oxford-instruments.com
Etch Chemistries:	Chlorine-based and fluorine-based chemistries, restricted use

Name:	**GSI,** Tool ID 06
Type:	plasma-enhanced chemical vapor deposition (PECVD) system
Manufacturer:	GSI http://www.groupsciences.com
Materials:	deposition of dielectrics - SiOx, SixNy

Name:	**MCS**, Tool ID 07
Type:	Barrel / parallel-plate plasma asher/etcher
Manufacturer:	MCS
Chemistries:	oxygen, CF4: organic removal and dielectric etching

D. Thermal

Name:	**CVD**, Tool ID 102
Type:	4-stack diffusion furnace, 6" capable
Manufacturer:	CVD http://www.cvdequipment.com
Chemistries:	Wet/dry oxidation, forming-gas or inert anneal

Name:	**RTA**, Tool ID 10
Type:	single-wafer rapid thermal processor (RTP), 6" capable "Solaris 150"

Manufacturer: SSI http://www.ssintegration.com
Chemistries: Inert and reducing atmospheres

Name: **Lindberg**, Tool ID 14
Type: single tube furnace for annealing small samples
Manufacturer: Lindberg Industries
Chemistries: Inert, reducing, and oxidizing atmospheres

E. Lithography

Name:	**EVG,** Tool ID 22
Type:	mask aligner, Model 620, 6" capable
Manufacturer:	EV Group, Inc. http://www.evgroup.com
Name:	**Suss**, Tool ID 21
Type:	mask aligner, model MJB-3, 3" capable
Manufacturer:	Suss MicroTech http://www.suss.com
Name:	**TRE,** Tool ID 109
Type:	pattern generator and mask stepper, model CC251
Manufacturer:	TRE/Electromask
Name:	**Heidelberg,** Tool ID 109B
Type:	laser writer, model DWL-66fs
Manufacturer:	Heidelberg Instruments http://www.himt.de
Name:	**Laurell [1-4]**
Type:	Resist Spinners, model WS-400B-6NPP-LITE-IND
Manufacturer:	Laurell Technologies http://www.laurell.com
Name:	**Headway**
Type:	Resist spinner, 6" capable, model PWM32-PS-CB15
Manufacturer:	Headway Research http://www.headwayresearch.com
Name:	**Yes1,** Tool ID 202A
Type:	Vacuum Pretreat oven with HMDS vapor, model 3TA
Manufacturer:	Yield Engineering Systems www.yieldengineering.com
Name:	**Yes2,** Tool ID 202B
Type:	Vacuum image reversal oven with HMDS and NH_3 vapor, model 310TA
Manufacturer:	Yield Engineering Systems www.yieldengineering.com

F. Metrology

Name: **Leitz,** Tool ID 27
Type: inspection microscope
Manufacturer: Ernst Leitz GmbH http://www.leica-microsystems.com

Name: **Zeiss**, Tool ID 26
Type: Inspection Microscope
Manufacturer: Carl Zeiss, Inc. http://www.zeiss.com/

Name: **Alphastep,** Tool ID 24
Type Alpha Step IQ surface profilometer
Manufacturer: KLA-Tencor http://www.tencor.com

Name: **Rudolph,** Tool ID 25
Type: Rudolph EL ellipsometer
Manufacturer: Rudolph Instruments http://www.rudolphinst.com

Name: **Nanometrics**, Tool ID 29
Type: spectroscopic reflectometer, NanoSpec AFT
Manufacturer: Nanometrics, Inc. http://www.nanometrics.com

Name: **AFM,** Tool ID 30
Type: Veeco/DI 5000 tapping/contact AFM (outside of CR)
Manufacturer: Veeco Instruments http://www.veeco.com

G. Other

Name: **SRD8,** Tool ID 215
Type: Spin-rinse dryer, 8" capable
Manufacturer: (To be determined)
Location: Thermal/Plasma Bay

Name: **SRD6**, Tool ID to be determined
Type: Spin-rinse dryer, 6" capable, two-chamber
Manufacturer: Verteq
Location: Wet Process Bay

Name: **CPD,** Tool ID 11
Type: Liquid CO_2 critical-point dryer "ThermoCube"
Manufacturer: Solid-State Cooling, http://www.sscooling.com/