Laboratory Usage & Safety Manual

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1 Scope

This document is a reference manual covering the basic operational policies for use of the facilities of the Cornell NanoScale Facility (CNF). It applies equally to both resident and non-resident users, and governs both safety and laboratory use rules. All users are expected to have read and understood these procedures. The laboratory is a multi-user facility with over 600 users having access around the clock. The facility houses millions of dollars of fragile equipment; it also houses chemicals which pose significant hazards if handled incorrectly. This booklet attempts to document acceptable operating behavior for use of the CNF. It is impossible, however, to define a policy for every conceivable situation. Rules and policies are no substitute for common sense. Under these conditions, anyone who fails to act in a professional, safe and responsible manner while in the CNF will be banned from further use of the facility at the discretion of the management. Users' suggestions and feedback on the facility, its staff, its operation, and its equipment are welcome at all times. Please feel free to direct your suggestions to whomever you feel most comfortable with, from an individual staff member to lab management or the Executive Committee.

2 OSHA Lab Standard

This laboratory operates under the Occupational Safety and Health Administration (OSHA) Laboratory Standard, 29CFR 1910.1450. The Lab Standard establishes the rights of laboratory workers and mandates training programs, monitoring and other actions by the laboratory. CNF applies the training requirements of the Lab Standard to all laboratory users, even non-employees. Compliance with the provisions of the OSHA Laboratory Standard is documented in this Lab Safety Manual and in the Cornell Laboratory Safety Manual and Chemical Hygiene Plan. This document is available for access from the Cornell Environmental Health and Safety (EH&S) web site at www.ehs.cornell.edu. Questions regarding this Safety Manual or a user's rights under the OSHA Lab Standard should be first directed to the CNF Safety Manager. Issues can be raised to the Cornell Chemical Hygiene Officer if further action is needed. This Lab Safety Manual forms the major part of the Chemical Hygiene Plan for CNF mandated by the OSHA Laboratory Standard and should be considered in its entirety to be part of the written Chemical Hygiene Plan (CHP). Compliance by the laboratory with the rules and procedures in this booklet is thus dictated by Federal regulation. This booklet, along with the mandatory chemical safety training, is also expected to be sufficient training and notification for the New York State Right-to-Know regulations for Laboratory Workers. Laboratory Workers are expected to have a technical level sufficient to understand everything in this booklet.

Other requirements of the Lab Standard are:

• Training for all laboratory workers in Hazard identification and safe operating practices.

• Standard Operating Procedures
• Medical Examinations or consultations for laboratory workers under certain conditions
• Training and availability of Personal Protective Equipment
• Application of appropriate Engineering Controls to limit employee exposure
• Special precautions/procedures for particularly hazardous materials
• Exposure Monitoring when appropriate
• Record keeping

The Laboratory Standard supersedes most OSHA workplace requirements for laboratory workers. The major features of the Lab Standard and the Cornell CHP will be explained to users during orientation sessions. Users should also personally refer to the written Lab Safety Manual & Cornell CHP as needed.

3 Lab Overview

3.1 Lab Access / Orientation Process

An orientation and training process is required before any new user can access to the facility. Upon completion of the proper documentation, the orientation sessions may be scheduled. For new projects, a Project Proposal (Appendix A) must be filled out and the project approved by the CNF User Manager. Once an approved project is in place, the following forms are required before the orientation session can be attended:

For Cornell researchers (including visiting scientists):
New User Application – Cornell (Appendix B)

For all researchers external to Cornell:
New User Application – External (Appendix C)

All Cornell users must have their application signed by the principal investigator for their CNF research project. All external users must complete the application form which includes a Memorandum of Understanding, an agreement between their institution and Cornell University. This legal agreement must be signed by an officer of their institution (not the principal investigator or department head). Normally, the New User Application will be sent to the outside user several weeks prior to the scheduled visit.

The three parts of the orientation are:
Part I – A walk-through of the facility which covers an introduction to the facility, basic cleanroom protocols, and general equipment usage rules (~ 2-2.5 hours).
Part II – A classroom presentation concentrating on chemical safety in the facility but also covering cleanroom protocols and general facility rules (~ 2-2.5 hours).

Part III – This session mostly covers chemical safety in the facility through a video presentation followed by small group interaction in the cleanroom (~2 hours).

Part I is usually done on Monday mornings and part II is usually done on Monday afternoons. Part III is done by appointment and includes a written quiz. They cannot all be done in the same day due to information overload. A limited number of spots are available in each orientation group; therefore it is important to get the paperwork filed on time to ensure a spot in the training.

To participate in orientation, users must
• Have completely read and understood this Lab Safety Manual
• Have a completed New User Application with original signatures on file at the CNF
• Be appropriately attired for clean room access (See section 4.3)

In all three sessions, the staff member will be looking for evidence that the user understands the language, rules, procedures, and consequences of working in the facility. The staff will evaluate whether the user can and will work safely in the laboratory. Actual approval for access is dependent upon their recommendation in these areas. The laboratory management may deny or restrict access based upon this evaluation.

3.2 Facility Conduct Expectations

The CNF is a national academic research facility that exists to support nanoscale research for many users, both internal and external to Cornell. Given the number of users the facility serves, we generally need to operate in a more restrictive way than other smaller facilities. The Staff and Management of the CNF have implemented all reasonable measures to ensure that the laboratory provides a clean and safe working environment.

It is the responsibility of all users and staff to act in a professional, courteous, and safe manner at all times while in the facility. Users violating the operating and safety rules of the facility or endangering the safety of themselves or other users may have their access restricted, suspended, or revoked at the sole discretion of the management.

Users are expected to be awake and alert at all times while in the facility labs. Sleeping in any of the labs will result in a suspension of lab access. Additionally, running in the lab, rough play, or other disruptive actions will not be tolerated and may result in suspension of lab access.

Safety is an overriding concern in all CNF laboratory activities. All operations must be undertaken with the safety of both the individual user and other users as

the primary consideration. As a general rule, anyone violating any safety rule or otherwise compromising his or her personal safety or the safety of others will be denied access to the laboratory. Suspensions may be for several days, a week, or permanently. These suspensions are at the sole discretion of the facility management. Ignorance of the rules, lack of common sense, language difficulties, carelessness, and being short on time are not adequate excuses for unsafe behavior. In general, if a user is not certain on what the proper procedure is for something, it is better to stop and ask staff than to try and guess what to do.

For the most part, rules on chemical use are formulated on the basis of basic chemical knowledge, the properties of individual chemicals, and common sense. In many cases, rules have been created in response to specific incidents of chemical misuse by users. In addition, a large volume of state and federal law covers chemical use in the workplace and disposal of waste. Some may believe our rules are restrictive and unnecessary, but they are required to maintain safety when you have several hundred users working in the same area. In spite of rules and staff supervision, the primary responsibility for safety rests with the individual user.

We encourage you to email your concerns or observations to safety@cnf.cornell.edu at any time. We welcome your suggestions regarding safety and laboratory procedures.

3.3 CNF User Communication

The CNF has a web site geared toward current CNF researchers at www.cnfusers.cornell.edu. This is the main point of communication from the facility management to current users concerning equipment status, facility closures, etc. Please check the web site often to stay informed on facility issues. Additionally, the staff uses email and phones as the main communication methods with individual users. Users should maintain up to date contact information in CORAL so that they can be reached by staff. Instructions on how to update your information in CORAL can be found on the CNF web site.

Safety issues or concerns about lab policies should be sent to the facility Safety Committee by emailing safety@cnf.cornell.edu. This contacts all the staff who can respond to an issue and is better than emailing the staff individually.

3.4 Computer Abuse

Computer abuse is a violation of university policy, and may subject the abuser to various disciplinary actions from CNF management, the campus judicial system, and legal authorities. Abuses of the computers at CNF will have the same results as violations of CNF safety rules ranging from denial of access to the computers for a period of time to permanent exclusion from the facility. Note that this policy

covers ALL computers at CNF, from the networked systems to the individual computer workstations. Computer abuse includes, but is not limited to:
• Using CNF computer systems or networks without proper authorization, or for unauthorized purposes, including using or attempting to use an account not issued to you;
• Tampering with or obstructing the operation of the CNF computer systems or networks, or attempting to do so;
• Inspecting, modifying, distributing, or copying software or other data (whether this is system software, data, or files of another user) without authorization, or attempting to do so;
• Supplying false or misleading information or identification in order to access CNF's computer systems, or attempting to do so.

A longer description of computer abuse may be found in "Cornell University Policy Regarding Abuse of Computers and Network Systems" at http://www.cit.cornell.edu/policies/university/privacy/abuse/.

3.5 Facility Governance and Appeals

The management of the facility (the Director, the Director of Operations and the Laboratory Manager) is responsible for the continued operation and existence of the facility. Use of the facility by any User is at the sole discretion of the management. The staff are responsible for maintaining and enhancing the equipment resources of the facility, and for assuring that the operational policies of the facility are followed. Authority and responsibility for safe operation of the laboratory flows from the Executive Committee to the Director to the Director of Operations to the Laboratory Manager and to the staff. On matters involving equipment usage or safety, you must follow the direct instructions of the staff. Both staff and Users are expected to act in a courteous and professional manner at all times. Deviations from this norm by either students or staff should be reported to the Safety Manager or the Director of Operations immediately.
If at any time you, as a User, feel that you have been unfairly treated by a staff member or strongly disagree with the rules imposed by a staff member, please discuss the situation with the Director of Operations. The sequence of appeals is from the Laboratory Manager to the Director of Operations to the Director. In extreme cases, an appeal can be made to the Executive Committee of the CNF.

3.6 Disclaimer

CNF makes a best effort to provide highly functioning tools and expertise available to assist users. Research processes provided at CNF are experimental and inherently exhibit some variability and risk. CNF neither guarantees success, nor does it warranty that process runs will produce identical results. Good practices dictate that users should amply test each process step using pilot or witness samples to verify critical steps to improve overall yield. Even then a process flow can yield unexpected or underperforming results. In addition, advice

from staff is based on many years of experience and can save significant time in achieving results. However, the user is ultimately responsible for the outcome of the fabrication process and staff members are held harmless.

3.7 Areas of the lab

CNF resources are housed in Duffield and Phillips Hall. The areas accessible to users are:

Main Office (250 Duffield Hall)
Lobby: The entrance area is a meeting place, not a lounge. This area is also the receptionist's office. The front door is locked except during the normal business day.

Conference Room: When not needed by the staff or scheduled meetings, users may use the conference room as a study and discussion area. Please keep the area neat. Use of the conference room for non-CNF private meetings, seminars, and exams is not encouraged, is subject to approval, and must be scheduled in advance with the receptionist.

Staff offices: The staff are located in 250, 262, and 258 Duffield Hall. Check the staff directory on the web site or at the entrance to 250 Duffield to determine where a given staff member's office is located.

Coat Racks and Lockers: The hallway outside the cleanroom has lockers for storing noncleanroom items (coats, backpacks, etc.) while in the cleanroom. Lockers are assigned on a temporary or permanent basis dependent on the user activity level. Do not store items in the main office or conference rooms as these rooms are locked during the evening and weekends.

Terminal Room (155 Philips Hall): This area contains computers and printers for use by CNF users for CAD work, Internet access, etc. This area is restricted to CNF users only. Please do not allow other people into this space.

Clean Room: Located on the first floor of Duffield Hall, the cleanroom contains most of the equipment of the CNF.

Break Room: Located next to the entrance to the cleanroom, this break area has coffee and tea service, a sink, refrigerator, whiteboard, and a few computer terminals. It is available to all users 24 hours a day to meet and take a break from their work.

CNF Noncleanroom Labs (224 & 228 Duffield): These noncleanroom laboratories contain two chemical hoods and various pieces of equipment.

Visitor's Offices: Temporary office space is available by request for visiting users on a first come, first serve basis. Upon request, short and long term visitors will be provided with space and a key. There are also a few staff offices in this area. Please respect each other's things in this area.

3.8 Hours of Operation

The laboratory is generally open 24 hours a day, 7 days a week, including most holidays. Certain instruments and procedures may have restrictions during evenings and weekends (See section 5.6 regarding the buddy system).

3.9 Facility Closures

Although the facility is generally open 24 hours a day, the CNF does have two periods during the year when the labs are unavailable. The labs are generally closed to users for several days following Memorial Day (the last Monday in May) due to campus-wide maintenance work. Additionally, the facility is closed for the Winter Holiday from about December 23rd until about January 3rd with the actual dates varying from year to year. Check with the CNF Users website for more specific information as the shutdowns approach. Additionally, the facility occasionally has intermittent closures due to variety of reasons such as unplanned facility maintenance issues, chemical spills, and other emergencies, with these closures generally lasting less than a day.

3.10 Laboratory Services

A variety of house services are used throughout the facility to support the equipment, including compressed air, laboratory vacuum, and house (dry) nitrogen. The house nitrogen is used throughout the lab in the N_2 guns for blowing off wafers, for dry boxes, etc.

A house vacuum cleaning system is located in the cleanroom for house cleaning needs. It is used for cleaning up dirt and debris, broken glassware & wafers, etc. Switches throughout the lab will turn on the system which will then stay on for a preset time before automatically turning off. Several vacuum cleaning hoses and numerous vacuum cleaning outlets are located around the laboratory. The house vacuum system is never to be used for cleaning up liquid or chemical spills.

High purity deionized (DI) water is available at all the chemical benches from the white gooseneck faucets as well as the blue tipped spray handles. DI Water is expensive to produce and the use of it should be minimized. While thorough rinsing is needed for many processes, DI faucets or dump rinse stations should not be left running unnecessarily. City water is available from the metal or gray gooseneck faucets as well and is good for the rinsing of empty bottles and glassware.

3.11 Lab Phones

Phones are provided throughout the laboratory for the use by staff and users. The phones can be used to call other Cornell extensions and local phone numbers only. Toll or long distance calls cannot be placed from these phones without a Cornell access number. The facility phones are not a substitute for office phones for Cornell Users. Users should not routinely make or receive calls at the CNF. The facility will not routinely take messages for users. Cell phones are allowed in all areas of the facility, but should not be used when working at chemical hoods, even with the use of a hands-free device.

To call other Cornell extensions, simply dial the last 5 digits of the number (i.e. for extension 255-2329, dial 5-2329). To dial an external number, dial 9 first, and then the number.

In an emergency, dial 911 from any campus phone, or use the red phones located around the facility. From a cell phone, dial 255-1111 to reach the Cornell Emergency Dispatch.

3.12 Intercom Use

The labs and offices of the CNF are equipped with an intercom system to allow staff and users to locate each other. Instructions on the use of the intercom system are posted by the phones. Staff request that users only page the offices when needed to reduce the distractions for those working at their desks.

4 General Facility Policies

4.1 Access cards

Lab access control is done through two cards issued to users of the facility, the proximity card and the photo wearable. The proximity card is a University issued ID card that contains an RF ID chip in it that is read using the proximity card readers located on the lab doors. For Cornell researchers, this ID is their faculty/staff/student ID card issued to them by Cornell University. For external users, a Cornell ID listing them as a Duffield Affiliate will be issued on their first visit. The Duffield Affiliate ID card is only used to access the doors in Duffield Hall and provides no other benefits on campus.

The photo wearable is a photo ID badge that all researchers are required to wear when in any of the CNF facilities. The photo wearable makes it easier for staff to identify users and to learn their names, as well as assisting in keeping the facility secure. The photo wearable is simply a picture ID and is not used for any door activation. The photo wearable is color and letter coded with the following codes:

Code	Definition

Black C	CNF User
Red CU	Undergraduate CNF User under restriction
Blue AC	Authorized CNF User – User who is allowed extra privileges.
Green N	NBTC/CNF User
Red NU	Undergraduate NBTC/CNF User under restriction
Blue AN	Authorized NBTC/CNF User - User who is allowed extra privileges.
Yellow SC	CNF Staff
Yellow SN	NBTC Staff
Yellow SD	Duffield Hall Staff
Orange VM	Tool Vendor / Maintenance Worker

Undergraduate CNF Users Under Restriction will start with M-F 8am-6pm access only. After 50 hrs of lab time, reasonable tool usage, and demonstration of safe lab practices will be granted “extended access” M-F 8am-11pm. After 100 hrs of lab usage and reasonable tool usage Undergraduate users will be granted full access privalages.

Access cards and photo wearables are issued for the sole use of one person on a specific approved user project. Sharing of these cards or permitting unauthorized access to the facility is not allowed. As these cards are the keys to the facility, they should be treated like one’s own house or car keys. If you lose your access card or photo wearable, there will be a replacement fee which may be charged to your Cornell account. These access cards are the user’s authorization to enter the facility. Persons without access cards specifically issued to them are not allowed in the facility, except for brief tours accompanied by an authorized user (See section 4.2). Your card is essentially your documentation that you have received the required orientation and safety training. Non-authorized persons are thus prohibited from accompanying, observing, and helping users at work. Non-authorized persons are thus also prohibited from the role of laboratory “buddy”. Please see section 5.6 regarding the buddy system. Lending an access card to someone else is a serious violation.

4.2 Visitors

Tours of the cleanroom should be limited to valid technical visitors such as sponsoring agencies, collaborators, and prospective researchers. Casual visitors such as friends and family can be shown around the public hallway outside the cleanroom. Additionally, a thorough video tour of the facility is available on the CNF web site or a 15-minute DVD is also available for viewing by appointment in the conference room.

Tours should be limited to a walkthrough of the facility, generally last no more than 1 hour in length, and should not include any demonstrations of equipment or processing steps. The purpose of a tour is to give the visitor an overview of the

processes and types of equipment available in the facility. It is not for instruction in processing techniques or for demonstrations on how to operate equipment.

Visitors must be signed in with the receptionist prior to the cleanroom tour. Tours given outside normal business hours can be arranged ahead of time by the user giving the tour. Visitor badges will be issued when you arrange the tour and must be returned when you are done.

For safety reasons, tours should be limited to no more than 8 people. A single user may escort a group of up to 4 visitors on a tour, while two users are needed for groups of 5 to 8 people. Groups larger than that should be coordinated well in advance with the facility staff to avoid excessive load on the cleanroom.

A key item to remember is that the user is responsible for the actions and safety of their guests when touring the facility. Generally, staff is available for assistance with tours if enough notice is given. Contact the Public Relations staff member for information.

4.3 Lab Dress Code

The lab has a unified dress code, so the requirements are the same whether you are working in the cleanroom or in the noncleanroom labs on the second floor of Duffield Hall. This dress code is based on industry-wide prudent practices when working in areas that contain hazardous materials. This dress code only applies to the lab spaces of the facility, not the offices or computer labs.

In general, a user's clothing should be clean before entering the lab spaces, even the noncleanroom labs. Users should not come to the facility with clothing that is dusty or dirty from previous work. Users should also avoid clothing that tends to shed a lot of fibers like fur, fake fur, mohair, etc. This can contaminate even the noncleanroom spaces.

4.3.1 Shoes

Shoes must be closed toe shoes that fully enclose the heel and the top of the foot. Sandals, open weave shoes, or shoes that expose the top of the foot are not allowed. Additionally, the shoes must not have a high heel or deep cleats that may hold mud or other dirt in them. Socks or stocking are also required.

The shoes must be clean and dry when you enter the facility. During the winter months this can be a particular challenge due to the amount of snow, slush, and salt on the sidewalks around Duffield Hall. Even after drying off, these shoes will track in salt and other contaminants into the facility. Therefore, during these types of weather, users need to bring a change of shoes that are not worn outside, to prevent contamination of the cleanroom with the water and salt.

4.3.2 Pants

Pants must run from the shirt to the ankles. Shorts, short pants, or skirts/dresses are not allowed. In the summer months, wearing 'hospital scrub' style pants overtop of shorts is a popular option.

4.3.3 Shirts

The shirt must run from the top of the arms to the pants. Tank tops, halter tops, and spaghetti strap tops are not allowed.

4.3.4 Safety Glasses

Safety glasses must be worn at all times in the labs. Safety glasses may be purchased in a variety of styles from the CNF, or a user may provide their own, providing they meet the ANSI Z87.1-2003 standard. Safety glasses may only be removed when using optical microscopes. Users should be sure to remember to put them back on when they step away from the microscope. Safety glasses are not a substitute for Face-shields when working with chemicals.

4.3.5 Contact Lenses

Contact lenses are allowed in all areas of the facility. In the past, it was not considered good laboratory practice to wear contacts in any laboratory, but the American Chemical Society changed its' recommendation, and the CNF has adopted its practice.

4.4 Allowed / Prohibited Items

To maintain a safe working environment, certain items are not allowed in the facility lab spaces. Below is a list of common items that are either allowed or prohibited in the facility. This list does not cover everything, so if a user is not positive an item is allowed, they should check with facility staff before bringing it to the facility. This list only covers the labs areas, and not the offices or computer rooms.

Prohibited	**Allowed**
Eating or drinking Gum, cough drops, mints, chewing tobacco, etc. Smoking (prohibited in all Cornell buildings) Music playing devices (MP3 players, stereos, etc.) – including listening to music on a laptop or cell phone	cell phones single-sided headsets for cell phones (only to be used for talking, no music listening allowed) cameras (still & video) PDAs, laptops Handheld electronic games (PSP, etc)

Additional restrictions on items allowed in the cleanroom are covered in section 6.2

4.5 User storage

Cleanroom space is at a premium, and therefore, large amounts of storage in the cleanroom are not available. A limited amount of storage space, mostly in the form of small bins, is available for a user's use in the cleanroom. Each bin will generally hold a box of masks, a box of wafers, and a notebook and a few small tools. Typically, one bin is allocated per active researcher. These should be used for keeping only currently needed samples, masks, and tools. Do not store junk, old samples and masks, and everything ever done at the CNF in them. No chemicals of any kind may be stored in the user storage area. Chemicals are to be stored only in the appropriate chemical cabinets.

Bins are assigned to users based on their usage of the facility. Users should only store items in bins assigned to them or their research group. Do not take over a bin assigned to users who have left the facility. Instead, contact the appropriate staff to inform them of the change and see if the bin can be reassigned. Temporary storage bins can be assigned to users who are not resident at Cornell. No additional dry boxes, desiccators, cabinets, etc. may be left in the laboratory without permission.

All items in the cleanroom should be clearly labeled with the user's name and the name of the user's research group. The staff periodically disposes of things left unlabeled or belonging to inactive researchers.

4.6 Facility Billing

All Users (academic, federal, and industry) are charged by the hour for the use of most instruments. Equipment charges help pay for the expendables and maintenance costs associated with that tool. Academic, Federal, and non-academic users are charged at different rates. Non-academic rates are chosen to be comparable to those charged by commercial suppliers of equivalent services, where applicable, and to cover the full cost of operation. Academic and Federal users are subsidized by the main NSF grant. Academic user fees are for bona-fide academic research only by students, post-doctoral researchers, and full time university staff members. Employees of companies may not use visiting scientist status at Cornell or elsewhere to receive academic rates. Assignment in questionable cases is at the sole discretion of the management.

Users will be billed at the end of each month for accumulated user charges. For Cornell Users, this is via a journal voucher. External users should supply a purchase order number against which charges can be billed. Failure to pay user charges will result in cancellation of the project. Users should discuss any issues concerning charges with the User Program Manager.

Cornell users need to inform the CNF Cornell Accounts Representative, in writing or by email, of any change to their account numbers. If the user's department

provides the CNF with a replacement account number, it will be used. It is important to use current, accurate account numbers at all times to avoid bounced charges and unnecessary book work. Users wishing to charge to multiple accounts need to have special arrangements made.

4.6.1 Equipment / Cleanroom Charges

Instrument charges are assessed for the entire time you use the tool, including setup and any cleaning steps required after operation. Some steps that use high cost materials, such as the evaporation of previous metals, have a separate materials charge to pay for these expensive supplies.

A daily entrance fee is charged to all users for each day they enter the cleanroom. This fee covers lab consumables such as gloves and wipes, cleanroom garment laundering, chemicals, etc. The facility also stocks items needed for research that are sold to the users as needed, such as photomasks, wafers, wafer tweezers, cleanroom notebooks, etc.

4.6.2 Annual Fee Cap

In recognition of the value of intense users and to allow easier budgeting, CNF has implemented an annual cap on user fees.

User	Annual Fee Cap
Academic – US	$16,000
Academic – International Federal Industrial	$58,500

The cap period is started the first day of the month in which work commences. Once the user has accrued equipment charges totaling the cap, future equipment charges are assessed at 20% the normal rate for the rest of that 12 month period. This cap is administered per person, not per group, and applies only to equipment use, not supplies or material charges or remote work performed at the facility. The cap is used to promote research at CNF, not to enable cheap production. It may not be used if it excludes reasonable access to the tools by others, and it should not be used exclusively for one tool. The cap is not an excuse to wastefully use equipment; violations of the intent will be noted and further access denied. If you have questions about the cap and how it is administered, please contact the User Program Managers.

4.7 Citation Requirements

The CNF is supported by the National Science Foundation through the National Nanotechnology Infrastructure Network. It is important for users to properly cite the support of the facilities of the CNF in all publications and presentations made possible by work performed at CNF.

For papers, a suggested acknowledgement reads: “This work was performed in part at the Cornell NanoScale Facility, a member of the National Nanotechnology Coordinated Infrastructure (NNCI), which is supported by the National Science Foundation (Grant ECCS-1542081).”

In presentations, listing the Cornell NanoScale Science & Technology Facility along with your other acknowledgements will suffice.

5 Equipment Policies

Access to the laboratory does not of itself permit use of any particular instrument. With few exceptions, the equipment in the facility is hands-on equipment for the users. Each major instrument is under the charge of a staff member referred to as the equipment manager. That equipment manager will train users on that instrument. When they are satisfied, the user will be authorized to use the system without further supervision. Much of the equipment in the facility is highly complex and delicate. In most fabrication facilities, direct hands-on access to this type of equipment by the end-user would be severely restricted or prohibited. The CNF views hands-on access as an important part of the educational process. Each instrument necessarily has rules and operational procedures which are set by the staff to assure the continued operation of the instrument. Violation of these procedures or carelessness in operation can result in damage to the equipment, down-time and considerable expense. Consequently, careless or damaging use of equipment will result in suspension of user privileges, either for a specific instrument or the facility as a whole.

5.1 Equipment Training Requirements

Each piece of equipment at the facility is under the responsibility of one or more full time staff members. These staff members are generally responsible for tool maintenance, training, and process development. The staff, with facility management, determines the equipment policies regarding allowed and prohibited operations on the tool. Each tool has instructions for user operation of the tool. These instructions may vary from a single sheet posted at the tool, to a more detailed manual, or a supplement to the operating manual provided by the original equipment manufacturer (OEM).

Before using any piece of equipment at the CNF, users must be trained by staff who are authorized to train on that equipment. Users cannot be trained by other users, or by staff not authorized to train on the tool. If you are ever uncertain, check with the primary staff member in charge of the tool. It does not matter much how experience a user has with similar equipment, as our policies concerning the operations allowed may be different than other facilities. During a user’s first visit, the hosting staff member will often run many of the pieces of equipment for the user to help the project make some initial progress. It is

important to understand the difference between a staff member demonstrating how they are running the tool, and official tool training. Again, if a user is uncertain at any time, they should check with the staff member to determine if they are being trained on tool operation. Users accessing tools or other lab facilities acknowledge that they have received the prescribed training from an authorized CNF staff member prior to doing so.

5.2 Equipment Interlocks

CNF uses a computer-based system, called CORAL, to control equipment access and to also record equipment usage charges. Users will need a CNF computer account to access the system. During orientation, use of the CORAL system will be demonstrated. CORAL does not actually turn on any instrument, but it does enable/disable the instruments. Users may be logged onto several instruments at once and they may log off them individually. Users must remember to log off, or they will generate large erroneous charges. When leaving, users should check the system monitors located around the facility to make sure that they are not still logged onto an instrument. The CORAL status screen can also be accessed from the CNF Users web site.

Users are responsible for logging out of CORAL for each tool use. Failure to do this may result in a large charge to your account. Since having a logged in status prevents other lab users from making reservations and discourages other users from seeking the “busy tool”, their work is delayed and CNF experiences a loss in fees. Each user is therefore responsible for the charges thus accrued. Repeated offenses may result in additional lab restrictions.

Note: you may access CORAL on any Internet-connected, Java-capable computer through the link on the CNF User’s web site.

All users are issued a computer account as individuals. Users must log in with their own account when logging into instruments. “Group” use is not acceptable. Some tool may still utilize paper log sheets. Be sure to write complete information legibly to avoid erroneous charges.

5.3 Equipment Information Sheets

Each major piece of equipment in the CNF has an Equipment Information Sheet (EIS) posted on it. An example EIS is shown in Appendix D. The sheet is a single page summary sheet of important information regarding the tool. It lists the staff members in charge of the tool, highlights important safety information including any buddy requirements (see section 5.6), processing and material restrictions, and any limitations on scheduling of the tool. Copies of the EIS are available on the CNF Users website on the tool web pages. These summary sheets do not replace tool training or manuals, but instead are to be used for quick reference of important information.

5.4 Problems with Equipment

Problems with the operation of the equipment should be reported to the staff member in charge of the tool, which is a two step process. The first step is to file a trouble report in CORAL using the 'Equipment Actions – Report Problem' menu item. This CORAL form will notify the proper people of the issue and list the tool in CORAL with a yellow caution light. The second step is to fill out a pink Trouble Sheet (Appendix E) and prominently attach it to the front of the tool. This makes certain other users going to use the equipment are warned of the potential problem on the tool. It is important to remember to do both steps in the process. In cases where the primary tool manager is out of town, an email or voicemail left for them will not automatically go to the backup but the CORAL trouble report will reach all the staff that needs to know. Additionally, the CORAL reporting system allows the facility to track issues with equipment and address problematic tools.

In no cases should a user attempt any repairs to the tool beyond what is explicitly allowed in the facility operating instructions for the tool. As with all things, if a user is uncertain if it is OK, they should check with staff before taking action. The equipment in the facility is very expensive and much of it is very delicate. Considerable damage can be done at a great cost of both money and downtime by careless attempts to fix things.

Users should not call the staff at home in the evenings or on weekends about minor problems with the equipment or their process. It will have to wait until the next workday. Obviously, major problems like fire, smoke, or equipment alarms should be reported immediately. If a user in uncertain about contacting staff, they should call the Laboratory Manager first. Any emergency involving injuries, fire, chemical spills, etc., should be reported to Cornell EH&S first, then to the appropriate staff.

If you feel you are due a refund based on the malfunction, please indicate this in the comments to staff section of CORAL. The incident will be investigated and if CNF staff find that the tool did malfunction, charges for that run will be credited. CNF will not refund charges that were incurred for processing steps that preceded the incident even if the malfunction renders the samples inoperative. Failures that may have been avoided by following better procedures or guidelines will not result in a refund.

5.5 Equipment Scheduling

CNF equipment is reserved through CORAL. For high demand tools, there may be limitations on the length of reservations and how many reservations a user can place in advance. Information on any scheduling restrictions will be covered during tool training and can also be found on the Equipment Information Sheet.

If a user is going to be late for a reservation, they should delete and reschedule their time on the tool. If a user is more than 15 minutes late for their reserved time on a tool, the reserved time may be claimed by anyone in the lab. Failure to cancel an unneeded reservation is inconsiderate to other lab users and causes inefficient utilization of resources. The CNF realizes that all projects require a certain process flow between instruments so that one problem can throw off an entire process schedule. Also, processes can take longer than anticipated. Thus while it is encouraged to sign up ahead, users should also encourage be flexible and cooperative with other users in stretching, sharing, and relinquishing time slots.

Non-resident users working under the direction of a staff member have priority for system access during the normal workday (8 AM. to 6 PM.). This priority does not extend into the evenings or weekends. This is not an excuse for indiscriminate bumping of scheduled users except in an extreme emergency. Both the staff member host and the non-resident user should make a reasonable attempt to schedule time on each system well in advance. Irresolvable conflicts will be handled by the Laboratory Manager. Priority access for non-Cornell users is provided due to the significant operating funds provided by the NSF for the CNF User Program. Visits by non-resident users are scheduled with the host staff member as much as three months in advance. It is the responsibility of the non-resident user to initiate such scheduling. All scheduled non-resident visits need to be coordinated with the User Program Manager to avoid conflict for resources.

5.6 Buddy System

The laboratory is open for most use 24 hours a day, 7 days a week. Some processes and equipment though have restrictions on usage during hours staff are not present in the facility, referred to as outside 'normal business hours'. For the facility, normal business hours are defined as 8 AM – 6 PM, Monday through Friday, except for staff holidays. The staff holidays are listed below. The staff holidays are independent of the Cornell academic calendar; staff generally does not get time off during school breaks.

Holiday	**Date**
Memorial Day	Last Monday in May
Independence Day	July 4th
Labor Day	First Monday in September
Thanksgiving (and the day after)	Fourth Thursday in November (and the day after)
Holiday Break (facility is closed)	December 25th through January 1st

Outside normal business hours, some processes and equipment in the facility require a buddy to be present. A buddy is defined as an approved CNF user who can assist the tool operator in case of an emergency. The buddy system is used

mainly for wet chemical use, which is further described in section 8.6.2, but it can also apply to equipment usage. Information on any buddy restrictions will be given during equipment training. Additionally, information regarding this can be found on the Equipment Information Sheet (EIS) for the tool.

6 Cleanroom protocols

The first floor laboratory is a clean room which includes the togging room. Users must be properly attired and follow the designated procedure for gowning in order to avoid generating unnecessary particles in the clean room. Proper cleanroom behavior is important to ensure the cleanliness of the cleanroom and the ability to perform state of the art nanoscale work. Even if a researcher feels their work is not sensitive to particles, it is important to recognize that this is a shared-use environment where other researchers need a clean facility. The following guidelines cannot cover every situation, so again, if a user is uncertain on the proper protocols to follow, talk with staff before proceeding.

Every time something is brought into the cleanroom, more contamination is carried with it. One aspect of keeping the cleanroom clean is to minimize the amount of material brought into the facility. Only items needed should be brought into the cleanroom. Section 6.2 covers the items that are expressly forbidden from the cleanroom. Section 4.3 covers a general dress code for the entire facility that is doubly important for the cleanroom. It is important for the user to become familiar with these restrictions and come prepared appropriately for working in the cleanroom.

Special ventilation equipment is used and extensive housecleaning procedures are implemented to assure some level of cleanliness in the laboratory. The level attainable is limited by the number of users using the facility, the informality of our operations, and design compromises made to reduce construction and operation costs. The clean room is nominally Class 1000; i.e., fewer than 1000 particles larger than 0.5 micron per cubic foot of air (~ an ISO M6 rating).

6.1 Cleanroom Suit Protocols

The cleanroom suit consists of three parts: the hood, suits, and booties. Proper gowning technique is important to ensure the cleanliness of the garments and the facility is maintained.

Before entering the cleanroom, users should make certain they meet the clothing requirements listed in section 4.3. Then to enter the cleanroom:

- Put on the shoe covers outside the cleanroom
- Enter the cleanroom and place all items being taken into the cleanroom on the counter.
- Hair and beard nets are available to assist in keeping hair covered.

- Put the cleanroom hood on with the barcode on the inside. The hood is often packaged inside out so check it carefully. Snap the hood under the chin.
- Put on the cleanroom suit being careful not to drag the suit on the floor in the process. Tuck the bottom of the hood into the suit, zip it up, and snap the top snap.
- Put on the booties, tucking the legs of the suit into the boot. Connect the strap across the top of the foot and tighten it snugly. Snap the top of the boot to the back of the suit leg.
- Using the spray bottle, moisten a cleanroom wipe with the water / Isopropanol solution and wipe down all the items being brought into the cleanroom.

When exiting the cleanroom, simply reverse the steps, placing the coverall, hood, and boots on a hanger, and labeling it with a name tag. The name tags are special color coded tags only used to identify the suits on the rack. The photo wearable ID should not be used for this purpose. Continue to reuse the gown upon each entry. Every Monday morning, the gowns are pulled from the togging room and sent out for laundering. So, the first time entering the cleanroom after Monday morning, get a new cleanroom suit and locate the proper name tag in the bins.

Once in the cleanroom, the cleanroom suit should never be opened or unzipped. If something under the suit is needed, return to the togging room to open the suit and retrieve it. Anything that a user needs access to while in the cleanroom (i.e. cell phones, PDAs, etc.) should be taken out while in the togging room and wiped down.

6.2 Allowed / Prohibited Items

In addition to the items not allowed in the CNF lab spaces (listed in section 4.4), the cleanroom has additional limitations to maintain the clean environment.

Prohibited	**Allowed**
cardboard and paper	plastic items
pencils	cleanroom paper & notebooks
cloth items	pens
hats & coats	synthetic fabrics (polyester, nylon)
	Paper items sealed in plastic

All items that are going to be brought into the cleanroom must be wiped down in the togging room to clean off surface dust and oil.

7 Facility Hazards

7.1 Laboratory Hazards

Hazards in the laboratory fall into two general categories. First, the facility uses a variety of compressed gases, some of which are toxic, highly toxic, corrosive, flammable, or explosive. The use of these gases is thus strictly regulated as an accident with any of these could be catastrophic. These hazards, however, can and have been minimized by the proper use of engineering controls, such as use of proper equipment, proper confinement, ventilation, sensors, purges, safety valves, etc., and by procedural controls implemented by the staff (See section 7.7).

The second, more troublesome category of hazard, concerns wet chemicals, i.e. the acids, bases and solvents commonly used in lithography and etching. These are “hands on” hazards and in a multi-use facility like the CNF, are hard to control by engineering. It is precisely because they are considered “ordinary” by many users that they present a serious hazard. The chemicals commonly used in the facility can cause severe burns, tissue damage, organ damage, asphyxiation, and genetic damage if improperly used. These chemicals can enter the body by inhalation, ingestion, or absorption (either directly through the skin or through gloves) and may have either long or short-term health consequences. In addition, improper use of solvents can result in a major fire. “Ordinary” chemicals are thus definitely not hazard free. Users are expected to treat all chemicals with appropriate respect and to be aware of all possible reactions which may be created, either intentionally or by accident.

7.2 Definition of a Chemical

Chemicals, from a regulatory perspective, are defined as any material that is not a common household item. Therefore, in addition to the common acids and solvents we traditionally think of as being chemicals, industrial grade cleaners, soaps, adhesives, lubricants, etc. are therefore defined as chemicals as well. Users need to keep this in mind when bringing new materials into the facility.

7.3 Chemical Safety Information

7.3.1 Sources of Chemical Information

The Materials Safety Data Sheet (MSDS) is a convenient, condensed source for information on the properties of any chemical. The MSDS is a federally mandated document which must be supplied by the manufacturer or seller of a chemical. It contains in summary form, the chemical composition, the physical and chemical properties, toxicology data, and instructions for handling, spill control, and waste disposal. As a matter of good habit, users should read the MSDS for every chemical that they handle. Safety data sheets for all chemicals approved for use

in the laboratory are available on the CNF Users web site. An example MSDS can be found in Appendix F.

7.3.2 Terminology

The following terms are often encountered when reading about the properties of chemicals and the toxicity of chemicals, for example, on the Material Safety Data Sheets. Simple definitions are included here to help understand the properties of common chemicals when referring to the MSDS or other references. This is not intended to be a complete reference on Toxicology or Chemical Safety.

7.3.3 Chemical Properties Terms

Pyrophoric chemicals spontaneously ignite in air. No source of ignition (spark) is needed as they react spontaneously when exposed to oxygen. Silane is an example of a pyrophoric gas used in the facility.
Flash point is the minimum temperature of a liquid at which it gives off sufficient vapor to form an ignitable mixture with air. Liquids with a flash point near room temperature can be ignited very easily during use.
Exothermic Reaction is a reaction which produces heat (releases energy).

7.3.4 Types of Exposure

Acute Exposure as used in toxicology refers to a short term exposure. It has nothing to do with either the severity of the exposure or the severity of the effect. The type of exposure occurring during an accidental chemical spill is properly described as an acute exposure.
Chronic Exposure as used in toxicology refers to a long term exposure. Again, it has nothing to do with the severity of the exposure, the severity of the consequences, or the duration of the consequences. Chronic exposures can be the result of chemicals in the workplace, the home, or the environment. Chronic exposures are usually the result of carelessness, ignorance, or neglect, and not the result of an accident.
Local Exposure refers to exposure limited to a small area of skin or mucous membrane.
Systemic Exposure means exposure of the whole body or system, through adsorption, ingestion, or inhalation.

7.3.5 Types of Effects

Acute Effects refers to the duration of the symptoms. Acute means symptoms lasting a few hours or days. Again, it has nothing to do with the severity of the effects.
Chronic Effects are long term effects, manifested by prolonged duration and continuing injury.
Local Effects occur in a small area, at the place of contact.
Systemic Effects occur throughout the body, or at least away from the point of contact.

Allergies and Hypersensitivity are reactions by particular individuals to particular chemicals, caused by heredity or prior overexposure. Hypersensitive individuals should avoid exposure to the offending agents.

7.3.6 Exposure Levels

TLV - Threshold limit value. This is actually TLV-TWA (time weighted average) but is commonly called just TLV. It is the (averaged) level to which a person can be exposed 8 hours a day, 5 days a week forever, without adverse health effects. These levels are set by ACGIH (governmental and industrial hygienists), and adopted into law by OSHA (Occupational Safety and Health Administration). This level is most relevant to chronic (long term) exposure to chemicals in the work place. Short term exposures in excess of TLV are thus not necessarily hazardous. This value is not particularly relevant to the laboratory situation. It is sometimes used as a guideline, however, since short term exposure to < TLV should be very safe.
IDLH - Immediately Dangerous to Life and Health. This level represents the maximum value for which a 30 minute exposure will result in no irreversible or escape impairing effects, i.e. the maximum level which will not cause you to pass out or sustain irreversible organ damage. It is the value most appropriate to sudden, one time accidental exposures.
STEL - Short Term Exposure Limit- Actually TLV-STEL. Maximum concentration to which you can be exposed for 15 minutes, up to 4 times a day without adverse effects.
PEL - Permissible Exposure Limit- The statutory equivalent of TLV.
LD50 - The dose at which 50 % of those exposed will die. Separate levels apply to various modes of exposure (inhalation, dermal, etc.). Usually expressed in terms of mg per kg of body weight; often measured for mice and rats, for obvious reasons. All these levels are approximate, with considerable inconsistency between various sources. It is obvious that one cannot do well controlled experiments on human subjects. It is thus wise to be conservative in estimates using these numbers.

7.3.7 Toxic Effects

Carcinogen - A substance producing or inciting cancerous growth.
Mutagen – A substance capable of inducing mutations.
Teratogen - A substance causing damage or death to a fetus.

7.4 Chemical Authorization

Because of the large number of users in the laboratory, the facility keeps a close tab on chemicals used in the laboratory. Only specifically authorized chemicals may be used in the laboratory. Most standard processing chemicals have been pre-authorized; Materials Safety Data Sheets for these are available on the CNF Users web site. No other chemicals may be brought into the facility until they have been approved!

The Chemical Safety Officer may issue approval based on a review of the MSDS and other relevant information provided by the user. To submit a new chemical for review, submit a new chemical request form, which is available on the CNF Users Web site (electronic MSDS required). Approval of new chemicals is not guaranteed; new chemical request may be turned down if they are too hazardous or are incompatible with other use of the laboratory. The approval process can take 1 – 2 weeks as chemical compatibility, waste disposal, and other issues must be resolved. Researchers should plan accordingly when needing new chemicals approved. Do not bring any chemicals or have them shipped to the CNF prior to receiving approval for them.

7.5 Shipping of Chemicals

If a user is shipping approved chemicals to the facility from their own institution, it is important that they are shipped following all Department of Transportation (DOT) laws for hazardous shipments. This generally requires that the person packaging the material has received official DOT training for shipment of hazardous materials. Users should check with their home institution's Environmental Health & Safety (EH&S) organization for more information regarding shipping chemicals.

7.6 Transporting Chemicals

Duffield Hall has a strict policy prohibiting chemicals in all public areas of the facility. That means that users cannot carry any chemicals into the facility, even approved chemicals. All transporting of chemicals into the facility must be done by staff. The chemicals should be taken outside of the building to the loading dock where a staff member can then transport the material through the Hazardous Material Corridor, which is not open to the user community. The staff member will then place the material into the research lab for the researcher to utilize.

7.7 Toxic/Corrosive Gases

The gases used within the facility for processing are generally supplied under high pressure from steel compressed gas cylinders. In most cases, these cylinders are housed in special gas cabinets and fitted with a variety of high purity valves, regulators and flow control devices. Gas cylinders must be treated with respect in all cases. An enormous amount of energy is stored in the compressed gas. In addition, many of these gases are toxic, or at least severely corrosive. Finally, improper use of gas cylinders and valves can result in contaminated gas and ruined samples and equipment. Compressed gas equipment in the facility is not user serviceable. Gas bottles are to be changed only by the appropriate staff members.

The following section covers some properties of the major hazardous gases used in the facility. This list is not necessarily exhaustive but is meant to cover the major gases and the major hazards present in the facility.

7.7.1 Silane

Silane (SiH_4) is used for the deposition of polysilicon, silicon nitride, and silicon dioxide in the MOS area and PECVD systems. Silane is pyrophoric, meaning it will spontaneously ignite in air at concentrations between 4% and approximately 90%. The silane gas cylinder is located in a ventilated cabinet. The bottle is fitted with a flow restricting orifice and a flow limit valve. These limit the flow of gas from the bottle so that even under catastrophic system failure the concentration is kept below the lower explosive limit.

7.7.2 Chlorine

Chlorine gas is used in several of the etching systems. Chlorine is severely corrosive and is choking to breathe. Chlorine forms HCl in the lungs, causing severe tissue damage which can be fatal. As with many other corrosive gases, the effects of exposure may not be noticed for a few days. In all cases, medical attention should be sought immediately following exposure, not at the onset of symptoms. For your reference the following values relate to chlorine exposure.
TLV 1 ppm
Odor Threshold 0.1 ppm
Coughing 30 ppm
Dangerous in 30 min. 40-60 ppm
Fatal with a few breaths 1000 ppm
Because of the small amounts used, the ventilation used, and the low odor threshold for chlorine exposure, accidental chlorine gas exposure is not considered a significant risk.

7.7.3 Anhydrous HCl

Anhydrous HCl (HCl gas) is extremely corrosive to almost everything, including stainless steel. Symptoms of exposure are similar to chlorine.

7.7.4 Anhydrous Ammonia

Anhydrous Ammonia (NH_3) is a severely corrosive alkaline vapor with a pungent odor. It is shipped in the cylinder as a liquid under its own vapor pressure, approximately 9 atm. It exhibits good warning properties, with an odor threshold of 50 ppm. Although the TLV is only 25 ppm, concentrations up to 300 ppm can be tolerated for an hour. Concentrations above 3000 ppm are suffocating, causing convulsive coughing and respiratory spasm. Such exposures can rapidly be fatal. Ammonia is used in the photolith, MOS and PECVD areas.

7.7.5 Liquid Nitrogen

Nitrogen is considered a hazardous gas as more people die of asphyxiation by nitrogen than by any of the “toxic” gases discussed here. Liquid nitrogen is used for many things in the laboratory. It is transferred to 160 liter dewars for cold traps. A large liquid storage tank is located outside the loading dock. Smaller tanks are filled on the loading dock. Procedures are posted for filling liquid nitrogen dewars. You must be instructed and authorized by building staff.

7.8 Highly Toxic Gases

Several highly toxic gases are used in the MOS and PECVD areas of the facility. These are limited to dilute diborane (0.2% B_2H_6 in helium) and dilute phosphine (2 % PH_3 in helium). Extreme care must be exercised with these gases, as exposure to small amounts can be fatal. Odor provides a poor warning for these gases as they are toxic at levels near or below the odor threshold. These gases are widely used in the semiconductor industry. Because of the extensive safety precautions normally taken, no accidental fatalities have been reported in the semiconductor industry using these gases.

7.8.1 Phosphine

Phosphine gas is a severe pulmonary irritant and an acute systemic poison. Overexposure can cause either sudden or delayed death due to lung destruction. It is a colorless gas with a fishy odor. Olfactory (smell) warning properties are better, however, than for arsine or diborane. It is toxic at levels near the odor threshold so it must be treated with great care. The OSHA standard PEL (permissible exposure limit) is 0.3 ppm averaged over an 8 hour shift. It is slightly heavier than air. Phosphine, like silane, is pyrophoric; i.e., spontaneously flammable in air. We usually don’t dwell on this, however, as its acute toxicity is a concern at much lower levels. Exposures of 2000 ppm for a few minutes are lethal; exposures of 7 ppm for several hours can be tolerated. The odor threshold for phosphine is near 1 ppm. The phosphine used in the facility is diluted to 2% in helium in the bottle. This adds an extra measure of safety to any accidental release of phosphine.

7.8.2 Diborane

Diborane is a colorless gas with a repulsive sweet odor. It acts as a pulmonary (lung) irritant. It is considerably lighter than air. The OSHA permissible exposure limit is 0.1 ppm averaged over 8 hours. Odor is not a reliable indicator of danger. Like phosphine and silane, it is pyrophoric. Fires involving diborane can produce other toxic fumes. The diborane used in the facility is diluted to 0.2 % in helium in the bottle. This significantly reduces the danger associated with an accidental release.

7.9 Toxic Gas Monitoring and Control System (TGMCS)

To maintain safety throughout the entire Duffield Hall building, a complex Toxic Gas Monitoring and Control System (TGMCS) has been installed. The system consists of over 100 electrochemical cell sensors in addition to computer monitored gas cabinets, exhaust sensors, and computer terminals. The electrochemical cells are extremely sensitive, and in most cases can measure the gas levels well below the TLV. The system response to an alarm is to immediately close all toxic gas valves, including the main cylinder valve. Since all toxic gas lines and valves are under external ventilation this should eliminate major problems.

Detection of a toxic gas will signal an evacuation using the fire alarm system. The appropriate response to this alarm is to evacuate the building immediately. Refer to section 10.5 for more information regarding emergency evacuations.

7.10 Specific Chemical Hazards (HF, carcinogen, etc)

Here is an overview of some specific or unique hazards from some chemicals commonly used throughout the facility. Users should review the MSDS for these and any other materials they work with.

7.10.1 Acetone and Flammable Solvents

Acetone is widely used throughout the facility. It is a very flammable solvent with a low flash point, (i.e. it can be ignited at a low ambient temperature). Because of this it presents a significant fire hazard. A spill of a gallon bottle of acetone could cause a catastrophic fire or explosion. Solvents should also be handled with care in the hoods and not used near hot plates. Spilled solvent can be ignited by the hot plates. The resulting fire could easily be drawn up into the exhaust ducts, again with catastrophic consequences. Spilled solvents can react explosively with chemical oxidizers present, e.g., peroxides, nitric acid. Spilled solvents should be contained immediately with spill control pillows. Environmental Health and Safety should be called for emergency response and to assist in clean up.

7.10.2 Hydrofluoric Acid

Hydrofluoric acid, HF, presents a significant hazard for personal injury. It is widely used in the lab in its pure form, diluted, and as the active component of BOE, Buffered Oxide Etch. It is used for etching silicon dioxide and particularly for stripping the native oxide prior to further processing. HF, however, is a very hazardous chemical, much more so than any of the other acids. Its danger comes from its effect on flesh. At the concentrations used in the laboratory, an HF “burn” is initially painless. The person may not even know that they have gotten a splatter on their hands, arms, face, or in their gloves. The acid however will silently eat away at the flesh. The fluoride ion is not consumed in this process and is soluble in tissue, so the damage penetrates deeper and deeper, until it comes to the bone where the excruciating pain begins. At that point though, it is too late to reverse the considerable tissue damage. At some point, it enters the

blood stream scavenging Ca^{+2} ions, and totally messing up the ionic chemistry of the nervous system. If left untreated, serious injury or death will result.

Simple washing of an HF splash is not sufficient to prevent damage. It does not wash off; it is already dissolving flesh and will continue to do so until medical attention specific to HF burns is given (including deep injections to neutralize the penetrated acid). Be sure that medical personnel know that it is an HF burn and know that it requires specific treatment different from a common acid burn. The recommended first aid for HF exposure is to rinse for 5 minutes and then immediately apply the Calcium Gluconate liberally to the affected area. Calcium Gluconate is located in the first aid cabinets in the facility.

HF etches silicon dioxide very well. Therefore, it also etches glass. It must not be kept in a glass bottle, used in a glass beaker, or disposed in a glass waste bottle. Plastic labware is available for this purpose. HF, like all other chemicals, must only be used in the chemical hoods. It is not acceptable to take a beaker of acid into the process area to strip a sample just prior to loading in a vacuum system.

7.10.3 Piranha Etch and Nanostrip

Piranha etch is a common name applied to a mixture of Hydrogen Peroxide and Sulfuric Acid (typically 1:5). It is extremely aggressive toward organic materials (e.g. flesh and photoresist residue, equally). It also removes heavy metal contamination. It is commonly used in the semiconductor industry for wafer cleaning. It is difficult to dispose of this mixture, however, as the waste continues to react and decompose for a long period of time. This builds up pressure in the waste bottles causing them to burst. Also if the solution is mixed very peroxide rich, one can make unstable compounds. Therefore, Piranha is not allowed to be mixed in the chemical hoods. It can only be processed in the Hamatech automatic wafer processer. Instead of Piranha etch, the facility stocks Nanostrip, a commercial stabilized version of Piranha.

7.10.4 Tetramethylammonium Hydroxide

Tetramethylammonium Hydroxide (TMAH) exists in several different forms at the CNF. The most common usage is in dilute (<4%) aqueous solutions for developing photoresists. These developers are often referred to by their brand names, so it can be hard to determine without the MSDS, which developers contain TMAH and which are based on other bases.

The CNF also has available concentrated TMAH in water (~25%) for selective etching of silicon. TMAH in this form is significantly more hazardous than the dilute solutions used in the lithography areas. In addition to the corrosiveness of the material, concentrated TMAH is also highly toxic. The increase in toxicity of concentrated TMAH is much more than the increase in concentration. It is important for users to treat the concentrated material with much more caution,

and not view it as simply a more concentrated developer. Users should note that there are separate waste containers for the concentrated TMAH, and that the usage of this concentration of TMAH is limited to the Base / Solvent hoods.

7.10.5 Chlorinated Solvents

Chlorinated solvents (chlorobenzene, trichloroethylene, and methylene chloride) are used in various resist processes. They are particularly bad for the human body, causing cancer, organ damage, etc. They should not be mixed with normal solvents in waste bottles. There are separate waste bottles for chlorinated solvents. As with most solvents, they can be readily absorbed through the skin. Rinsing of containers that contained chlorinated solvents requires a special procedure to ensure the material is completely removed. See section 9 for more information.

7.10.6 Glycol Ethers

Commercial photoresists and electron beam resists are dispersed in a variety of solvents. The composition of these mixtures is generally not disclosed on the bottle; you must look on the MSDS for it. One family of chemicals, the glycol ethers, is commonly used in photoresists, and masquerade under a variety of names. In addition, the common trade name “Cellosolve” is often thrown in. Methyl Cellosolve, Ethylene glycol mono methyl ether, and 2-methoxyethanol are all the same thing. Similarly, Cellosolve, Ethyl Cellosolve, 2-ethoxyethanol (2EE), and Ethylene glycol mono ethyl ether are all the same solvent. To further complicate things, each solvent has an acetate relative, so we have Cellosolve Acetate, Ethyl cellosolve acetate (ECA), Ethylene glycol mono ethyl ether acetate, and 2-Ethyoxy ethyl acetate which are again all identical.

Most photoresists contain one or more of these as solvents. The present solvent of choice is PGMEA (propylene glycol mono methyl ether acetate) also known as 1-Methoxy-2-propanol acetate. Members of this family of chemicals have been shown to be teratogenic and have other effects on reproduction in laboratory animals. A number of studies funded by IBM and others have found evidence that these chemicals can lead to miscarriage and other reproductive effects. To quote from the MSDS for AZ 2131 Thinner (2 Ethoxyethyl Acetate and N-Butyl Acetate) “In studies with laboratory animals, 2-ethoyxethyl acetate caused birth defects, increased fetal death, delayed fetal development, caused blood effects, testicular damage and male infertility.” The liquid and vapor are eye and respiratory tract irritants and may cause kidney damage, narcosis, and paralysis (in simple terms, it damages your kidneys, eyes, lungs and brains). Primary routes of exposure are inhalation, skin absorption, and skin and eye contact with vapors. N-butyl Acetate, the other component of this thinner, has a similar list of possible systemic effects. As with all chemicals, these are only the effects we know about. These experimental laboratory exposures were large amounts but nonetheless it is prudent to be careful with these solvents. Review Section 8.6

regarding use of the lithography chemical hoods to ensure that exposure to these compounds is minimized.

7.10.7 Peroxides

All peroxides are highly oxidizing materials. Considerable energy can be released in their reactions with common materials. Some peroxide compounds are unstable, and can explode. The Hydrogen Peroxide in the facility is over 10 X more concentrated than the solution used in the medical field and has a high contact risk. Extreme care should be used in mixing solutions containing peroxides. Peroxides are incompatible with all forms of organic solvents and flammable materials.

Users should be careful when disposing of pure hydrogen peroxide solutions in waste bottles. The waste should only go into waste bottles explicitly listed as accepting pure hydrogen peroxide. Adding pure hydrogen peroxide to an ammonium hydroxide / hydrogen peroxide or hydrochloric acid / hydrogen peroxide waste bottle can lead to rapid heating and breakdown of the peroxide, which can result in the waste bottle being over pressurized and rupturing.

7.10.8 Pregnancy

Users who believe they are pregnant should discuss laboratory use with their physicians. This need not severely restrict laboratory use but should nonetheless be discussed.

8 Wet Chemical Use

8.1 Labware

Clean glassware and plastic ware are available for use in the laboratory. Users are not authorized to appropriate a private stash of glassware for their own use. Glassware is washed in a special dishwasher and returned to the glassware rack by CNF staff.

8.2 Chemical Supplies

The facility stocks and supplies the chemicals commonly required for processing in the facility. Users are neither allowed to bring in their own stocks of these chemicals or to appropriate as a private stash any of these chemicals. The facility simply does not have room for researchers to have private bottles of chemicals. The one major exception to this is with resists and other expensive lithography chemicals, where research groups that purchase their own may store it in the facility for their exclusive use. Working stocks of chemicals are kept in the chemical cabinets located under the hoods or nearby. Extra stock is kept in service corridors, accessible by staff only, therefore users may not replenish the cleanroom cabinets.

Chemicals supplies carried from room to room in the lab must be carried in a rubber chemical carrying bucket or carts. Users carrying bottles within a single room or area are not required to use the rubber chemical bucket. All chemical containers moved outside of a hood must be sealed with a screw top lid. Open containers or containers with unattached lids may not be carried around the lab, even if they only contain water.

Users must not open a new bottle until the old one is empty. When a chemical bottle is emptied, it must be thoroughly rinsed before disposal in the chemical bottle trash. An automatic bottle washer located in the General Chemistry aisle is available for this function. Instructions on the use of this system are covered in the orientation. If the system is offline for any reason, users are still responsible for rinsing bottles manually at the sink.

Chemical bottles that contained chlorinated solvents like methylene chloride, must also be rinsed with isopropanol to get rid of the residual material before being rinsed with water (see Section 9.5). Chemical bottles that contained a polymer solution (photoresists, spin-on glasses, etc) need to have the polymer material completely rinsed out of the container before it can be disposed. Users must determine the correct solvent to do this and into what waste bottle the solvent rinse should go into. In many cases, Acetone is not the correct solvent for this. Contact the staff responsible for that area of the lab for assistance in the proper solvent choice.

Empty, clean, rinsed, uncapped bottles (both glass and plastic) go into the yellow waste can in the central process area (not in a normal waste basket). Do not cap them. The bottles must have no chemical or liquid residue in it. Custodians are not chemical waste handlers. Violations of this procedure carry very severe penalties.

8.3 Types of Chemical Hoods

The CNF classifies the chemical hoods into two groups: the Lithography Hoods, and the General Chemistry hoods, which include the Acid, Base/Solvent, MOS clean, and Electroplating/KOH hoods. The Lithography Hoods are limited to work involving solvents and mild bases for typical lithographic processing. In the General Chemistry Hoods, higher contact hazard materials such as acids and bases are used.

8.4 Personal Protective Equipment

8.4.1 Lithography Hoods

At all the Lithography Hoods, users are required to use a face shield and thick or thin nitrile gloves. Vinyl gloves are not allowed due to the low solvent resistance of this material. The thin nitrile gloves are only slightly resistant to many of the

solvents, but they give the user a few minutes to replace the glove after the solvent exposure. The face shield is to be worn whenever working in or near the hoods. Users should only handle the face shield from the top. Do not handle the face shield by the front as this can contaminate the clear portion of the shield, decreasing visibility.

8.4.2 General Chemistry Hoods

At all of the general chemistry hoods, the required Personal Protective Equipment (PPE) is a face shield, a nitrile apron, and the thick nitrile gloves (overtop the standard cleanroom gloves). Tape on the floor clearly marks the areas around the hood where the PPE is required to be worn.

Nitrile Apron
The apron is clearly labeled with a 'chemical side' that should face out when wearing it. This is to prevent chemical residues from the apron from coming in contact with the wearer.

Face Shield
The face shield is to be worn whenever working in or near the hoods. Users should only handle the face shield from the top. Do not handle the face shield by the front as this can contaminate the clear portion of the shield, decreasing visibility.

Nitrile Gloves
Thick green nitrile gloves are also required at all times. They are to be worn over the standard cleanroom gloves. While working in the hood, the nitrile gloves can quickly become contaminated by chemicals. If these gloves are used to handle items outside the hood, the chemical residues can spread to others who are not wearing PPE and they can be injured. To prevent this, the gloves should be removed whenever handling items outside of the hood such as phones, notebooks, sample holders, keyboards etc. When putting on or removing the PPE, the nitrile gloves should be the last item put on and the first item removed, to prevent transferring any chemical residues to the faceshield or apron straps.

The PPE should not be worn except in the immediate area of the chemical hood. Wearing the PPE around the lab will lead to transferring chemical residues into non-chemical areas of the facility. Tape lines on the floor clearly mark the area beyond which the PPE is not allowed.

8.5 Respirator Use Policy

In general, engineering controls (fume hoods, equipment interlocks, etc) in the facility are sufficient to prevent the need for users to use a respirator. Respirator usage is tightly controlled by OSHA, as improper usage can lead to a false sense of safety and a greater chemical exposure than without one. Users who feel that

they would benefit from the use of a respirator in the facility should discuss it with the Safety Manager to determine if it is appropriate.

8.6 Chemical hood Procedures

8.6.1 Hood Sign In

Before starting work in any of the General Chemistry / MOS hoods, users are required to sign in on the hood log sheet. Clearly and completely fill out the form. An example form is shown in Appendix G. This form allows for staff to audit usage of a hood as well as to help in understanding the root causes from incidents with waste bottles.

Do not overcrowd the hood by trying to have too many people work at the same time. The current user of the hood may request that others wait until he or she is finished. This should not be used to claim the use of a hood for an excessive period of time though, but should be used to make certain that the work is done safely.

8.6.2 Chemical Buddy

Users working outside of 'normal business hours' in the General Chemistry Hoods are required to have a chemical buddy present in the lab. This covers the time period between 6 PM and 8 AM weekdays, and all day weekends and holidays. The buddy system requires that another knowledgeable user be in the clean room, aware of the user working in the hood, and close enough to be of assistance in case of an accident. Minor incidents with these classes of chemicals can quickly become life threatening if the user is alone when the incident occurs. The responsibilities of a chemical buddy are to actively check (every 5 – 10 minutes) on the status of the user during their work in the hood, to assist the user in responding to chemical spills, and even to assist the user in seeking medical assistance if it is required. A user should not agree to be a chemical buddy if they are not prepared to assist in this manner.

Chemical buddies are required to sign into the hood with the user at the start of the work. The user is not allowed to sign the name for the chemical buddy. This is to make certain that the chemical buddy clearly understands that they are agreeing to be the buddy for that user. A chemical buddy should inform the user when they are leaving the facility so that they can seek another user to sign into the hood with them or stop their work. Ultimately though, it is the responsibility of the user working at the hood to make certain that the chemical buddy that has signed in with them is present while they work in the hood. A user may have a new chemical buddy sign into the hood with them at anytime. If the work lasts for many hours, the user and buddy should sign into the hood every couple of hours to document that the buddy is still present.

8.6.3 Checking Waste Bottles

Before starting work with a chemical in a hood, users should check the hood for the appropriate waste bottle for materials they will be working with. This helps to make certain that the user is in the correct hood for their work. For example, the cleanroom has two acid hoods, and to reduce the amount of waste bottles in each hood, certain acids are only used in one of the two hoods. If the waste bottle is full, a new waste bottle should be created before starting the work. Refer to Section 9 for instructions on how to create a new waste bottle.

Users may not arbitrarily mix chemicals together in the facility. Only specifically approved solutions can be made (See Appendix H). This is posted at each chemical hood. This policy is a result of how the facility disposes of waste. The lab only has certain waste bottles available and, if a user mixes a non-approved solution, they will have no place to dispose of it.

8.6.4 Chemical Containers

After a user has signed into the hood (if required), and checked the waste bottles, they should get the containers needed for their work. The labware should be made of the appropriate material and just large enough to easily work with the samples to be etched. Do not use containers that are too large for the samples, as this will use more chemicals than needed and create more waste to dispose. Disposal costs for chemicals are often much more than the original chemical costs so users should try to minimize wasteful use of the chemicals.

For most materials plastic, Teflon, or glass containers are acceptable. If the solution is to be heated, only a glass container should be used. If using a hydrofluoric acid containing solution, use a plastic or Teflon container since the chemical will attack glass. All containers are required to have covers on them. The U.S. Environmental Protection Agency (EPA) defines any uncovered container not in current use as an illegal disposal of the chemical by evaporation. Even if the user never plans on walking away from the container, lab policy requires that they have a lid for it. This policy is required for all containers including containers of water.

8.6.5 Container Labels

All chemical containers are required to have labels on them that clearly identify the contents. Many solvents and caustics look the same as water, so everything, including water, must be clearly labeled. Cleanroom post-it notes are available at each hood for the labels. The label must be clearly printed with the full chemical name, the user's full name, and the date. The label should be attached to the chemical container itself and not the lid or hood in front of the chemical if possible. If the label is attached to the lid, when the lid is removed it can be confusing which container contains which chemical. All containers are required to

be labeled regardless of whether the user is going to be present the entire time or not. The label should be present on the container before the chemical is poured.

8.6.6 Working with Chemicals

Users should be sure to understand the risks of all the materials they work within the hoods. The MSDS can be used to understand the properties and hazards of these materials. Here are a few specific things to keep in mind when working in the hoods:

- Be careful when pouring chemicals, as this is the most common time for spills or accidents.
- Users should plan out their work when they place the containers in the hood. Users should make certain that they don't need to carry a wafer dripping with chemicals over the length of the hood to get to the sink to rinse it.
- Be sure to take time and be careful with the chemicals. Not only will this help in producing good research, but it will also make the process safer.
- Avoid distractions while working at the hood. Do not take or make phone calls or engage in distracting conversations with other users. Focus on the work that is being performed.

8.6.7 Hot Plates

Hot plates may seem to be a very basic piece of lab equipment but they can be very dangerous if used in an improper manner with the chemicals in the facility. Hotplates are tightly controlled at the facility due to the risk of being left unattended and creating a hazardous situation or fire. To reduce this risk, the hotplates have special plugs that will only plug into outlets that are located in the General Chemistry hoods. The timers will shutoff power to the hotplate unless they are reset every 15 minutes. This is to prevent someone from forgetting a hotplate that has been left on. The hotplates in the lithography areas are not on timers, and should only be used for the baking of resist on substrates.

When using a hotplate, users are required to be present in the facility, or have someone designated to watch over the hotplate if they need to step out for a moment. The user should be actively checking on the material on the hotplate, using a thermocouple to monitor the solution temperature to make certain that the chemical is not heated to a dangerous temperature. This is especially important as the material is being heated up to the operating temperature, as small solution volumes can quickly heat up to a dangerous temperature. Only glass containers should be used on hotplates, no matter what temperature the material is being heated to. Due to this requirement, hydrofluoric acid solutions are never to be heated on hotplates in the facility.

Heating flammable solvents on hotplates is highly controlled due to the risk of a fire from the flammable vapors that will be generated. Only a very limited set of

solvents are allowed to be heated on hotplates in the Base/Solvent hood. This information is posted at the hood.

8.6.8 Waste Disposal and Cleanup

Once a user is finished with chemicals in a hood, the chemicals should be disposed of in the appropriate waste bottle. See Section 9 for information on how to dispose of the chemical waste. All chemical containers should be thoroughly rinsed with city water with special rinsing for any container that held chlorinated solvents (see section 9). The containers should all be placed in the dirty labware rack by the dishwasher, upside down so that they can drain. The labware should not have any chemical residues or smells. Facility staff will wash the labware and return it to the clean labware rack.

Thoroughly rinse any thick nitrile gloves off before throwing them into the regular trash cans. Any cleanroom wipes that have any chemical on them should be rinsed out as well before disposal in the trash. The hood should not be left with extra wipes, containers, hotplates, thermocouple readouts, gloves, etc. left out. All items should be returned to their proper places and the hood left clean, dry, and empty for the next user.

Chemicals should not be left in the hood for long periods to be reused by the researcher. Given the number of people in the facility, the lab does not have enough hood space to allow each researcher to have their own section of the hood for their chemicals. Chemicals that are to be used frequently over a period of a day may be left for reuse as this can also help reduce the amount of chemical waste generated. By the end of the day however, all chemicals should be disposed of and the container cleaned up. Chemicals that are hot may be left overnight and allowed to cool but an extra note indicating this should be posted on the container to show that it was not forgotten about. Substrates are allowed to soak overnight in chemicals if needed, but a note indicating this should be placed on the container, in addition to the standard container label. This should only be used occasionally and when needed by the process.

8.6.9 Summary

Here is a summary of the main differences between the Lithography hoods and the General Chemistry Hoods:

	Lithography Hoods	**General Chemistry Hoods**
Personal Protective Equipment (PPE) Required	Nitrile gloves (thin or thick) Faceshield	Green Nitrile Gloves Faceshield Nitrile Apron
Hood Sign In	None	Required for all work

Chemical Buddy	Not Required	Required for all work outside normal business hours
Chemical Containers	Glass or plastic containers with lids	Glass or plastic containers with lids
Container Labels	Required for all containers, including rinse water. Must list full user name, date, and full chemical or product name	Required for all containers, including rinse water. Must list full user name, date, and full chemical or product name
Waste Disposal	In the appropriate chemical waste bottle	In the appropriate chemical waste bottle

9 Waste Handling

Many different types of waste need special handling at the facility. In addition to chemicals, glass, batteries, sharps, and other items need special handling while disposing.

9.1 Glass / Silicon Waste

Broken and unbroken glass should not be disposed of in the standard trash cans, as it can cut the plastic trash bags and possibly injure the janitorial staff. The facility has several metal trash cans labeled for the disposal of glass waste. Silicon wafers and pieces of wafers should also be disposed in this trash. No other waste should be put into these trashcans. Empty glass chemical containers should not be placed into these trash cans, but instead should be placed into the yellow trash can for empty chemical bottles, located next to the bottle washer.

9.2 Sharps

Any trash that is sharp, such as a razor blade, needle, or other type of blade should be deposited into the yellow sharps bins located around the lab. They should not be placed into the normal trash cans to prevent injury to the cleaning staff.

9.3 Compound Semiconductor Waste

All waste pieces of Gallium Arsenide, Indium Phosphide, and similar compound semiconductors should be deposited into the small labeled bin located on the main process bench. This is to prevent arsenic contamination of the normal trash cans.

9.4 Chemical Waste

At the CNF, all chemical waste is collected in new 4 Liter plastic bottles with vented caps; no waste is to be poured down the drain. For Cornell users, it is

important to note that this is different than other labs on campus. The vented caps allow for excess pressure generated from any chemical reactions in the bottle to safely escape the container. These will only slowly vent excess pressure so it is important to minimize any secondary reactions in the waste bottle. Properly following Federal laws regarding waste handling is critically important, both to help keep our planet healthy, as well as to prevent large fines from being given to the facility due to pollution violations.

All waste labels for the waste bottles are prepared by the CNF staff. They are available at each hood on adhesive labels that can be easily attached to the new waste bottles located next to the sink. The waste labels for the Lithography Hoods are all common, while the General Chemistry Hoods have labels that are specific for each hood. Users should never alter or create a waste label. If the correct label for a chemical mixture cannot be found, then the user should leave the chemical in the hood and contact the Safety Manager for assistance.

One challenge is that the waste bottles sometimes only list the chemical names, while many materials used in the facility are referenced by the brand name. If a user is uncertain on which waste bottle to use, consult the MSDS for the material to determine the chemical compounds in the material. If it is still unclear, do not dispose of the material. Instead contact the Safety Manager for assistance. For example, many different kinds of chemicals are used in the lithography area that are called ‘developer’. Some are solvents that are disposed of in the Flammable Solvents waste containers while many others are aqueous base solutions that are disposed of in a different container. Users should never guess on the container to dispose waste into but should check the MSDS or with staff for clarification.

The waste bottles are kept in the back of the hood, properly labeled with the preprinted waste labels, and the vented caps on them. Do not overfill the waste bottles as this makes them more dangerous to handle. Signs in the hood indicate the proper fill level for the bottle. If a user has more waste than can fit in the existing bottle, they should fill the current bottle before pouring into the new one. Do not create a new waste bottle until the existing one is full. Having extra waste bottles in the hood creates more hazard for the work as there is less room to work, and more waste in the hood in case of an incident. The full waste bottles should be placed in the back of the hood. Facility staff come a couple of times a week to remove the full bottles. Any unusual reactions with the waste or bottles showing signs of a secondary reaction (bubbling in the waste, pressurized bottles, etc) should be reported to the Safety Committee immediately.

Only the original chemical mixture should be poured into the waste bottle. Any containers of rinse water used to rinse the substrates after etching should be

poured down the drain. Adding excess water to concentrated acid waste bottles can lead to overheating and pressurization of the waste container.

9.5 Chlorinated Solvent Waste

Chlorinated solvents (e.g. Methylene Chloride and Chlorobenzene) do not rinse well from bottles and other glassware. To properly remove the solvent residue from these containers they should be thoroughly rinsed with Isopropanol, with the rinse going into the Chlorinated Solvent waste bottle. Then the item should be rinsed with water, which may go down the drain.

9.6 Solvent Contaminated Items

Wipes, gloves, or other items that have resists or other spin on polymer solutions on them should not be disposed of in the standard trash cans. These polymer solutions will release the solvents into the air for a very long time, filling the room with solvent fumes that the air system can quickly spread throughout the lithography areas. In all the lithography rooms, special trash cans attached to the fume hoods are to be used for disposing of these items. The trash exhaust prevents the release of the fumes into the room.

If a user enters a room and notices a strong solvent smell, it should be investigated immediately, as olfactory fatigue will quickly set in. Olfactory fatigue is where the nose stops ‘smelling’ an odor after being exposed to it for a period of time. The first place to check are the trash cans to see if someone has improperly disposed of a resist covered item. If the source of the odor cannot be located, users should exit the area and contact staff.

10 Emergency Response

The facility can have many different types of emergencies. Although it is not possible to plan ahead for every type of possible emergency, the following sections cover the main types of emergencies that may occur with the appropriate response for each.

10.1 Emergency Phones

Red Emergency Phones are located throughout the facility. These are part of the university 911 phone system and are a direct line to public safety (the campus police). They know when and where an emergency phone is picked up off the hook. They can assist in sending police, an ambulance, or EH&S to assist with a chemical spill or exposure. The system is such that just picking up the phone without saying anything will result in campus police sending someone to investigate. Therefore if a red phone is accidentally picked up or bumped you need to stay on long enough to tell them there is no emergency. To access these emergency services from the regular Cornell phones dial 911. Calls made to 911

from a cell phone may be connected with the Ithaca Police, the Tompkins County Sheriff, or the State Police depending on which cell tower the call connects to. This may delay getting assistance, so the quickest way to get assistance on a cell phone is to dial 255-1111 to connect directly to the Cornell dispatch.

When calling in an emergency it is important to clearly communicate the type of emergency to the dispatcher. For medical emergencies it can be helpful to clearly indicate whether the medical emergency is chemically related or not. For example, the emergency response for someone having a heart attack is different than for a person who has had a large acid exposure.

Anytime emergency response is called in to the facility please have someone contact the Safety Manager, Lab Manager, or Building Manager at home to inform them of the event, no matter what time it is. The emergency contact information for this staff is available from any of the emergency signs posted on the room doors.

10.2 Emergency Response Equipment

Spill control kids are placed in several locations around the lab. Bottles of neutralization liquid are also available for use on acid and caustic spills. Emergency showers and eye washes are located around the facility as well. Most chemical burns, particularly in the eyes, should be washed for 15 minutes before seeking further medical attention. First Aid Kits are available by the main process bench and in the togging room. Tubes of Calcium Gluconate Gel are available there for application on hydrofluoric acid burns. This should be applied promptly, but is not a substitute for medical attention.

10.3 Chemical Exposures

Any major chemical exposure should be reacted to immediately by using the chemical safety shower. All clothing should be removed as soon as possible to assist in getting the chemical off of the body. Modesty should not prevent users from doing this. Other users should use the emergency phones to contact EH&S and request medical assistance for a chemical exposure. The injured person should fully rinse the affected area for 15 minutes and then seek medical treatment. If the exposure was to a hydrofluoric acid containing solution, the rinsing should only be for 5 minutes followed by liberal application of Calcium Gluconate Gel to the affected area, followed by medical treatment. Users affected by chemical burns should not worry about any chemical spill, but instead should take care of themselves and allow someone else to deal with the spill. After seeking medical attention for the exposure, the user should contact the Safety Manager, to inform them of the incident.

10.4 Chemical Spills

Users are primarily responsible for cleaning up any minor chemical spill they caused using safe and approved procedures. Training on the cleaning of chemical spills is covered in the chemical hood orientation. Users should request assistance from Environmental Health and Safety and the staff for any significant spill. Spill kits located throughout the facility contain various items such as spill pillows and wipes for soaking up larger spills. Neutralizers are available at the General Chemistry Hoods to assist in making the material safer to cleanup. Spill equipment that has chemicals in them should be placed in the yellow hazardous materials bags located in the spill cabinets and placed inside the appropriate hood. The bag should be labeled the same as any other chemical container with the chemical name, the user name, and the date.

For major chemical spills, spills releasing significant hazardous fumes, and for any unanticipated chemical reaction, users must evacuate the area or the laboratory and call Environmental Health and Safety. Any user may call for an evacuation of the laboratory at any time using the paging system. These "requests" must be honored by all users until such time as the situation is evaluated. Evacuate the area to a safe place but remain near the lab entrance to inform the emergency responders of the location and type of material spilled (if known). The user should also assist EH&S in getting copies of the MSDS for the materials. For spills that involve EH&S, please contact the Safety Manager, Laboratory Manager, or Building Manager as well, not matter what time the event occurs. Their emergency contact numbers are printed on the room emergency signs located at every room entrance.

In all cases except for the smallest incidental spills, users should notify the CNF Safety Committee (safety@cnf.cornell.edu) after the situation is resolved.

10.5 Building Alarms

The facility can have two types of audible alarms that evacuate the building: fire alarms and gas alarms. For a Fire Alarm, sirens and strobe lights will go off throughout the building while for a gas alarm only the individual floor will alarm. The response to both types of alarms is the same: users may take 5 – 15 seconds to secure whatever tool they may be working with before evacuating the facility. They should then calmly walk to the nearest exit of the facility and meet at the north entrance of the atrium, which is the end closest to the road. Researchers in the cleanroom should not return to the togging room to remove the cleanroom suit, but instead, should exit out the nearest door and remove the cleanroom suit when they reach the designated meeting point. Alarms that affect the second and third floors of the buildings will also initiate the closure of gates isolating the floor from the atrium of the building. Sliding doors will close at all entrance points to the building. To exit through a closed door, tap the green bar

at the end to have it briefly open. If the atrium is not in alarm, users may wait there until the alarm has been cleared by the emergency responders.

For both types of alarms, the system will automatically contact Cornell Police, who will dispatch the emergency responders (EH&S) to the scene. Users should not reenter the affected areas of the building until given the OK by the EH&S personnel on the scene. In addition to the Cornell Police, the system automatically contacts the appropriate CNF personnel. Staff may assist EH&S over the phone or in person depending on the type of incident that occurs.

All alarms should be treated as real. Occasional testing of the system is clearly announced throughout the building intercom system. If a user is ever in doubt about whether and alarm is real or not, they should proceed to evacuate, and then determine if the event was real once they have left the area.

10.6 Other Emergencies

10.6.1 Medical Emergencies

In medical emergencies, administer first aid, CPR, etc. as appropriate. First Aid kits are available at two locations in the cleanroom, in the togging room and in the cleanroom by the main process bench. These kits contain band aids, antiseptic, instant cold packs for bumps or sprains, gauze, and other bandages. They also contain a mask for assisting with giving CPR and Calcium Gluconate gel for hydrofluoric acid exposure. Users should also call EH&S using the red phones. EH&S or the Cornell Police will be able to request additional emergency medical personnel. For a heart attack, a CPR mask is available in the first aid kits. Additionally, Automatic External Defibrillators (AED) are available in a couple of locations in the building. Training is required to use these instruments, which has been done by several different people in the building.

10.6.2 Facilities Malfunctions, Leaks, and Alarms

Many parameters of the cleanroom are remotely monitored 24 hours a day by a facilities management group on campus. Issues such as exhaust fans failing, temperature or humidity control issues, or other functions are automatically reported to maintenance workers for correction. If exhaust fans shutoff, low flow sensors on the equipment and hoods will alarm, indicating that the exhaust is off. In these cases, the facility should be exited until the equipment can be restarted. In the case of a general power failure to the building, it will be very dark in the lab until the emergency generator turns on 5 – 10 seconds later. Emergency lights will then allow you to exit the facility normally. It will be necessary for the staff to bring equipment back up before general laboratory use can resume. Exhaust fans and air handlers will resume automatically. Situations requiring immediate attention, like water leaks, equipment smoldering, etc should be reported

immediately to the Lab Manager or Safety Manager. Phone numbers for the appropriate people are listed on all the doors to the various labs.

10.6.3 Incident Reporting

In addition to normal emergency response, all accidents involving chemicals and all accidents involving personal injury must be reported to the facility management in writing as soon as possible after the incident. Explanations should include the nature of the event, the procedures being followed or not followed at the time, and actions required to prevent future similar incidents. The Safety Manager can supply a form appropriate for this. In addition, for cases involving personal injury to employees, the university may require additional documentation.

11 Revision history

Version	Update
10.0	First release with revision history. Major rewrite of document for changes in Duffield Hall.
10.1	Updated web links to keep them current. Removed references to Carol Cleveland Replaced references to CAC with CORAL Section 3.6 – added information about break room Section 4.3.4 – updated safety glasses ANSI standard Section 5.4 – Updated information regarding trouble reporting
10.2	Updated references to blue nitrile gloves Added information concerning contacting Safety / Lab Managers for all emergencies in the lab Updated web links Edited for language
10.3	July 2010 Added Section 3.6 – Disclaimer Added language in section 5.2 Equipment Interlocks concerning charges for not logging out of tools
10.4 10.5	January 2015 Added text clarifying undergrad restricted and extended use. January 2018 Updated Cap Rates

Glossary

Buddy – an authorized CNF user who agrees to assist a user in case of an emergency that occurs outside normal business hours
CNF Users Website – website located at www.cnfusers.cornell.edu that is the main communication point from the facility to the users
CORAL – Open source software that is used to control access to the equipment interlocks and to determine equipment billing charges. This can be accessed through the Sunray Terminals or using the CORAL link on the CNF Users Website.
EH&S (Environmental Health & Safety) – Group that sets rules regarding worker and environmental safety for a company
Equipment Information Sheet – a one page summary sheet for each tool that lists the main safety and operational policies
Equipment Manager – staff member assigned primary responsibilities for a piece of equipment
MSDS (Material Safety Data Sheet) – a document produced by a manufacturer of a material that details the risks associated with that material
Normal Business Hours – 8 AM – 6 PM Monday through Friday, excluding staff holidays
NSF (National Science Foundation) – Office of the U.S. Federal Government that supports U.S. science efforts. The NSF is the main funding agency of the CNF
OSHA (Occupational Safety and Health Administration) – Office of the U.S. Government that sets rules for workers
Photo Wearable – a photo identification card that has the user's picture on it
PPE (Personal Protective Equipment) – equipment that is worn to protect a worker while they work with hazardous materials or equipment
Proximity Card – an identification card containing a radio frequency (RF) enabled chip that can be used to activate door locks
Safety Committee – A group of designated CNF staff members who help determine the facility safety policies
TGMCS (Toxic Gas Monitoring and Control System) – a complex system of sensors, switches, controllers, and alarms used to monitor and control the gas piping systems in Duffield Hall
User – a researcher who is trained and authorized to work in the CNF labs

Appendix A. Project Proposal

Project Proposal

Electronically fill out this proposal form, attach a project description and email the files to userprogram@cnf.cornell.edu. *Handwritten forms will not be accepted.*
(* - required fields)

Proposed Project Start Date _____ *Today's Date* _____

Project Information:

*Title _____

*Host Institution _____ *Host Department _____

*Proposing Institution Type _____ Funding Agency _____

PLEASE NOTE: Academic Projects must originate from degree granting institutions, and be paid through University Sponsored Research Funds. The Intellectual Property associated with the work must reside with the Academic Institution.

Principal Investigator:

*First Name _____ *Last Name _____ *Title _____

*Institution _____ Department _____

*Street _____

Street (cont.) _____

*City _____ *State/Province _____ *Zip/Postcode _____ *Country _____

*Phone _____ *FAX _____ *Email _____

***Billing Information:**
For Cornell projects please provide the Cornell Account #: _____
For all other projects, please provide a billing address:
Bill to Attention:

First Name _____ Last Name _____ Title _____

Institution _____ Department _____

Street _____

Street (cont.) _____

City _____ State/Province _____ Zip/Postcode _____ Country _____

Phone _____ FAX _____ Email _____

Project Proposal v2.0

Personnel Expected to Work on This Project:

First Name	Last Name	Title	Email
First Name	Last Name	Title	Email
First Name	Last Name	Title	Email
First Name	Last Name	Title	Email

Please attach a brief summary of the proposed research.

For Internal Use Only	
Project #:	
Account #:	
Host:	
Topic:	
Date Approved:	
Approved By:	

Appendix B. New User Application - Cornell

New User Application Cornell

Electronically fill out this application form and email the electronic file to userprogram@cnf.cornell.edu. Then print it, obtain the proper signatures, and turn the original signed hardcopy into the CNF Receptionist. Handwritten forms will not be accepted.
(* Required fields)

Part I. User Contact Information

*First Name | *Last Name | Title

*Street

Street (cont.)

*City | *State/Province | *Zip/Postcode | *Country

*Phone | FAX | *Email

*CNF Project # | *Cornell Account # | *Cornell NetID (required for computer access) | *Cornell Student / Staff ID Card #

*Department | *Academic Status

Part II. Project Principal Investigator Approval

The above individual will be working under my supervision on the specified CNF user project. The above information regarding his/her status at Cornell is correct. I understand that I must notify the CNF office regarding any change in this status. This user authorization is only for the duration of my CNF proposal. This authorization is only for the work on the above named user project as part of the individuals work for me while s/he is a resident at Cornell. Exceptions should be noted below. I understand that it is my responsibility to secure the return of all access card(s) at the completion of his/her term at Cornell or the completion of this work, which ever comes first. I agree to pay for all materials and instrument charges that may be required by current CNF policy from funds in either the above account or other accounts under my control. I understand that there is a one-time orientation/training fee of $400 per user, which will be charged against the above account. (There is no monthly fee.) Additional fees may be charged as per current CNF policy.

*Principal Investigator Signature | *Date

*Name of Principal Investigator

Part III. User / CNF Agreement

By signing below, the User warrants that he/she has been provided with the CNF Laboratory Usage and Safety Manual and has read and understands and agrees to abide by the usage rules and safety provisions discussed in this manual. While the User will be trained in general chemical safety before being allowed to use chemicals, and in the operation of the particular processing instruments required by his/her work, the User assumes primary responsibility for his/her personal safety. It is expected that the User will operate all instruments and equipment in a safe and professional manner, consistent with the operating instructions and the Laboratory rules. The User represents that his/her knowledge of chemistry and general laboratory practice is advanced enough to permit the safe pursuit of the project in question. The User acknowledges that the CNF is a research enabling center, that the User retains ultimate responsibility for project progress and development, and Cornell does not in any way warrant or assure a particular project result. Additionally, by signing this agreement, the User agrees to abide to the

Cornell University Code of Conduct
http://www.policy.cornell.edu/Campus_Code_of_Conduct.cfm

Cornell University Policy Regarding Abuse Of Computers And Network Systems
http://www.cit.cornell.edu/policy/responsible-use/abuse.html

_____ _____

*User Signature *Date

The following information is collected for NSF reporting requirements and is optional:
Gender Ethnicity Race

Part IV. Project Description

Describe in detail what specifically YOU expect to do at the CNF. Be as detailed as possible. Describe specific instruments, materials, processes and dimensions required.

CNF Approval

Rate Charged: Academic Federal Industrial

Application Approval: _____ Date: _____

Orientation Fee Charged: Yes No

	Date	Pass/Fail	Staff Initials
Part I			
Part II			
Part III			

Restrictions: _____

_____

_____

Appendix C. New User Application - External

New User Application External

Electronically fill out this application form and email the electronic file to userprogram@cnf.cornell.edu. Then print it, obtain the proper signatures, and turn the original signed hardcopy into the CNF Receptionist. Handwritten forms will not be accepted.
(* Required fields)

Part I. User Contact Information

*First Name | *Last Name | Title

Institution | Department

*Street

Street (cont.)

*City | *State/Province | *Zip/Postcode | *Country

*Phone | FAX | *Email

*CNF Project # | *Institution Type | *Academic Status

*Have you ever had a Cornell ID card before? Yes No
Please visit www.cnf.cornell.edu/cnf_questid.html to register for a Cornell Guest ID for computer access and enter that ID below.

*Cornell Guest ID (or former Cornell net ID)

Part II. Memorandum of Understanding

All Users (and their institutions) of the CNF Laboratory Facilities through the CNF User Research Program represent that they have read and understand and agree to the terms of this Memorandum of Understanding, and have asked any questions they may have in reference to this memo or any other information they have received before signing.
The User and his/her institution understand that his/her use of the laboratory is controlled by the provisions of the CNF National User Program through which he/she has a project. Laboratory use is provided only for research work in conjunction with the specific project described in the User's currently approved CNF proposal.
The User and his/her institution understand that he/she is not an employee of Cornell and that Cornell provides no Worker's Compensation or other Liability Coverage for the User's benefit. The User is deemed to be acting as a representative and employee of his/her institution during work at CNF. All Users will have their own health and accident insurance and the user institution must carry business liability ($1M) coverage. Cornell will not be responsible for any medical expenses that the User may incur.
The User and his/her institution shall release, hold harmless, and indemnify Cornell University, its officers, agents and employees from any and all claims, damages, costs (including reasonable attorneys' fees) and liabilities arising out of the User's use of CNF Laboratory Facilities other than those which result from the negligence of Cornell University, its officers, agents, or employees.

(**NOTE**: Institutional approval must be by an officer of the institution with appropriate authority, e.g. the Vice President for Research, Dean, or Director; NOT the Principal Investigator.)

*Institution

*Officer Name | *Officer Title

*Officer Signature | *Date

New User Application – External v2.0

Part III. User / CNF Agreement

By signing below, the User warrants that he/she has been provided with the CNF Laboratory Usage and Safety Manual and has read and understands and agrees to abide by the usage rules and safety provisions discussed in this manual. While the User will be trained in general chemical safety before being allowed to use chemicals, and in the operation of the particular processing instruments required by his/her work, the User assumes primary responsibility for his/her personal safety. It is expected that the User will operate all instruments and equipment in a safe and professional manner, consistent with the operating instructions and the Laboratory rules. The User represents that his/her knowledge of chemistry and general laboratory practice is advanced enough to permit the safe pursuit of the project in question. The User acknowledges that CNF is a research enabling center, that the User retains ultimate responsibility for project progress and development, and Cornell does not in any way warrant or assure a particular project result. Additionally, by signing this agreement, the User agrees to abide to the

Cornell University Code of Conduct
http://www.policy.cornell.edu/Campus_Code_of_Conduct.cfm

Cornell University Policy Regarding Abuse Of Computers And Network Systems
http://www.cit.cornell.edu/policy/responsible-use/abuse.html

*User Signature _____ *Date _____

The following information is collected for NSF reporting requirements and is optional:
Gender Ethnicity Race

Part IV. Project Description

Describe in detail what specifically YOU expect to do at the CNF. Be as detailed as possible. Describe specific instruments, materials, processes and dimensions required.

CNF Approval

Rate Charged: Academic Federal Industrial

Application Approval: _____ Date: _____

Orientation Fee Charged: Yes No

	Date	Pass/Fail	Staff Initials
Part I			
Part II			
Part III			

Restrictions: _____

Appendix D. Example Equipment Information Sheet

Hex #: 104 Equipment Information Sheet **CNF**

GCA/MANN 3600F PG

	Work Phone	
Manager: Garry Bordonaro	254-4936	**Calls to staff phones will be automatically forwarded to their cell phones during accessible hours. At other times leave a message or send them an email.**
Backup: Mike Skvarla	254-4674	
Backup: Edward Camacho	254-4853	

Safety

- No unusual hazards during normal operation
- No buddy system restrictions imposed on normal operation

Process Restrictions

Material Restrictions

- 3" - 7" 0.090" thick plates (165mm X 159mm write area)
- Back of substrate must be CLEAN - NO RESIST on back

Parameter Restrictions

- Set proper size in program as per manual (i.e. use 124mm for 127mm plate)
- Keep all data at least 3mm from edge of mask as defined above
- Fiducial marks on 127mm plates ONLY

Scheduling / Sign-up Restrictions

- Maximum 4 hour block reservations during daytime
- Maximum 12 hours reserved in advance (excluding overnight)
- No consecutive research group reservations
- Users/Groups may use any amount of unreserved time
- Additional individual restrictions may be imposed to maximize use

Requirements (Do Every Time)

- Check MODE (1MSM)
- Clean up - NO items in chamber

Prohibitions (Never Do)

- NEVER Leave chamber doors open
- NEVER Load/remove substrate EXCEPT at loading position
- NEVER Tighten screws on chuck - finger tight ONLY
- NEVER Get oil on stage surface
- NEVER Fix anything

Common Problems

Problem:	Root Cause:	Solution:
Focus error; Time Out	Wrong size plate, wrong plate position	Change plate size in job, move banking pins to proper locations
X-Y data range error	Data too big, label position wrong	Check data in CAD, check that label is within plate limits

Other Comments or Cautions

- Run TT and TQ before starting job
- Type Ctl-P to see job status/elapsed time
- Dose must be adjusted for large clear field masks

Printed: 10/22/2007

Appendix E. Trouble Report Sheet

CNF Instrument Trouble Report

******* Attach to Front of Instrument *******

Instrument Name: _____ Clearly!

Your Full Name: _____ Clearly!

Phone Number: _____ Email:_____

Date: _____ Time:_____

Level of Experience

How many times have you used this tool in the last 6 months?

<5 5-10 10-30 >30

Be sure to file an online trouble report after posting this notice!

Describe situation and problem completely and Clearly!

_____

_____

_____

_____

******* Do Not Use As Scratch Paper *******

Appendix F. Example MSDS

SHIPLEY

MATERIAL SAFETY DATA SHEET
MICROPOSIT S1813 PHOTO RESIST
41280 4.00 US US 11.06.1998 MSDS_US

1. CHEMICAL PRODUCT AND COMPANY IDENTIFICATION

Product Code	41280
Trade Name	MICROPOSIT S1813 PHOTO RESIST
Manufacturer/Supplier	Shipley Company
Address	455 Forest St. Marlborough, Massachusetts 01752
Phone Number	(508) 481-7950
Emergency Phone Number	(508) 481-7950
Chemtrec #	(800) 424-9300
MSDS first issued	2 July 1996
MSDS data revised	11 June 1998
Prepared By:	Amy C. Nichols
Local Sales Company	Shipley Company, 455 Forest Street, Marlboro, MA 01752 (508-481-7950)

2. COMPOSITION/INFORMATION ON THE INGREDIENTS

Components in Product

Component Name	CAS# / Codes	Concentration
Electronic grade propylene glycol monomethyl ether acetate	108-65-6	71.00 - 76.00
Mixed cresol novolak resin		10.00 - 20.00
Fluoroaliphatic Polymer Esters		0.01 - 1.00
Diazo Photoactive Compound		1.00 - 10.00
cresol	1319-77-3	0.01 - 0.99

3. HAZARD IDENTIFICATION

Main Hazards	- Irritant - Combustible - Nervous System - Skin - Eye - Kidney - Liver
Routes of Entry	Inhalation, ingestion, eye and skin contact, absorption.
Carcinogenic Status	Not considered carcinogenic by NTP, IARC and OSHA
Target Organs	- Nervous System - Skin - Eye - Liver - Kidney
Health Effects - Eyes	Liquid or vapor may cause pain, transient irritation and superficial corneal effects.
Health Effects - Skin	Material may cause slight irritation on prolonged or repeated contact. Repeated and/or prolonged contact may lead to: -

3. HAZARD IDENTIFICATION

	drowsiness - liver damage - kidney damage
Health Effects - Ingestion	A large dose may have the following effects: - drowsiness - liver damage - kidney damage
Health Effects - Inhalation	Exposure to vapor at high concentrations may have the following effects: - irritation of nose, throat and respiratory tract - liver damage - kidney damage

4. FIRST AID MEASURES

First Aid - Eyes	Immediately flush the eye with plenty of water for at least 15 minutes, holding the eye open. Obtain medical attention if soreness or redness persists.
First Aid - Skin	Wash skin with water. Obtain medical attention if blistering occurs or redness persists.
First Aid - Ingestion	Wash out mouth with water. Obtain medical attention.
First Aid - Inhalation	Remove from exposure. If there is difficulty in breathing, give oxygen. Seek medical attention if symptoms persist.
Advice to Physicians	Treat symptomatically.

5. FIRE FIGHTING MEASURES

Extinguishing Media	Use water spray, foam, dry chemical or carbon dioxide. Keep containers and surroundings cool with water spray.
Special Fire-Fighting Procedures	This product may give rise to hazardous vapors in a fire. Vapors can travel a considerable distance to a source of ignition and result in flashback.
Unusual Fire & Explosion Hazards	Pressure may build up in closed containers with possible liberation of combustible vapors.
Protective Equipment for Fire-Fighting	Wear full protective clothing and self-contained breathing apparatus.

6. ACCIDENTAL RELEASE MEASURES

Spill Procedures	Contain and absorb using earth, sand or other inert material. Transfer into suitable containers for recovery or disposal. Finally flush area with plenty of water.
Personal Precautions	Wear appropriate protective clothing. Wear respiratory protection. Eliminate all sources of ignition.
Environmental Precautions	Prevent the material from entering drains or water courses.

7. HANDLING AND STORAGE

Handling	Use local exhaust ventilation. Avoid contact with eyes, skin and clothing. Keep container tightly closed when not in use.
Storage	Store in original containers. Store away from sources of heat or ignition. Storage area should be: - cool - dry - well ventilated - out of direct sunlight

Other
Proprietary photoresist film contains approximately 2-4% of 2,3,4-trihydroxybenzophenone(THBP), which may sublime during soft-bake or hard-bake processing. THBP has low acute toxicity (LD50>5g/kg). Contact with eyes, skin or mucous membranes cause irritation.

To prevent accumulation of THBP on equipment surfaces and ventilation ducts, preventative maintenance program including regular cleaning should be implemented. Wipe surfaces using an appropriate cleaning solvent when possible. Provide adequate general or local exhaust ventilation during the cleaning process. In situations where this is not possible or where solvent or dust concentrations become excessive, use an air purifying respirator with an organic vapor/toxic particulate cartridge. When cleaning residual THBP, wear protective gloves and adequate protective clothing to prevent skin contact. Practice good personal hygiene to prevent accidental exposure. Clean all protective clothing and equipment thoroughly after each use.

8. EXPOSURE CONTROLS/PERSONAL PROTECTION

Occupational Exposure Standards

Electronic grade propylene glycol monomethyl ether acetate	Manufacturer recommends 30ppm 8h TWA and 90ppm 15 min STEL.
cresol	ACGIH: TLV 5ppm (22mg/m3) 8h TWA. OSHA: PEL 5ppm (22mg/m3) 8h TWA. UK EH40: OES 5ppm (22mg/m3) 8h TWA. Can be absorbed through skin.
Engineering Control Measures	Engineering methods to prevent or control exposure are preferred. Methods include process or personnel enclosure, mechanical ventilation (local exhaust), and control of process conditions.

8. EXPOSURE CONTROLS/PERSONAL PROTECTION

Respiratory Protection	Respiratory protection if there is a risk of exposure to high vapor concentrations. The specific respirator selected must be based on the airborne concentration found in the workplace and must not exceed the working limits of the respirator.
Hand Protection	Butyl rubber gloves.
Eye Protection	Chemical goggles.
Body Protection	Normal work wear.

9. PHYSICAL AND CHEMICAL PROPERTIES

Physical State	Viscous liquid
Color	Red
Odor	Sweet
VOC (g/l)	764.7
Specific Gravity	1.04
pH	Neutral
Boiling Range/Point (°C/F)	145.8/295
Flash Point (PMCC) (°C/F)	40.5-46.1 / 105-115
Explosion Limits (%)	Lower limit 1.5 at 20 °C. Upper limit 7.0 at 20 C..
Solubility in Water	Insoluble.
Vapor Density (Air = 1)	Heavier than air.
Evaporation Rate	Slower than ether
Vapor Pressure	Propylene Glycol Monomethyl Ether Acetate: 3.7 mmHg at 20 °C.

10. STABILITY AND REACTIVITY

Stability	Stable under normal conditions.
Conditions to Avoid	- High temperatures - Static discharge
Incompatibilities	- Oxidizing agents
Hazardous Polymerization	Will not occur.
Hazardous Decomposition Products	- oxides of carbon - oxides of nitrogen - acrid smoke and irritating fumes - phenols - carbon monoxide - toxic fluorine compounds

10. STABILITY AND REACTIVITY

11. TOXICOLOGICAL INFORMATION

Acute Data	Propylene Glycol Monomethyl Ether Acetate: Oral LD50 (rat) 8532mg/kg. Dermal LD50 (rabbit) 5000mg/kg.
Chronic/Subchronic Data	No data.
Genotoxicity	It was not mutagenic when tested in bacterial or mammalian systems.
Reproductive/Developmental Toxicity	Developmental effects were seen in laboratory animals only at dose levels that were maternally toxic.
Additional Data	None known.

12. ECOLOGICAL INFORMATION

Mobility	Propylene Glycol Monomethyl Ether Acetate: Koc is 0 - 50.
Persistence/Degradability	The product is partially or slowly biodegradable. BOD20 greater than 40%
Bio-accumulation	No data.
Ecotoxicity	The product is rated as practically non-toxic to aquatic species. Tests on the following species gave a LC50 of 161mg/litre: - fathead minnows Tests on the following species gave a LC50 of 408mg/litre: - daphnia

13. DISPOSAL CONSIDERATIONS

Product Disposal	Incineration is the recommended method of disposal. Dispose of in accordance with all applicable local and national regulations.
Container Disposal	Labels should not be removed from containers until they have been cleaned. Empty containers may contain hazardous residues. Dispose of containers with care.

14. TRANSPORT INFORMATION

DOT Ground:	Not Regulated per 49 CFR 173.150(f)(2)
UN Proper Shipping Name	Flammable liquid, n.o.s.
UN Class	(3) Flammable Liquid
UN Number	UN1993
UN Packaging Group	III
N.O.S. 1:	Propylene Glycol Monomethyl Ether Acetate
N.O.S. 2:	
Subsidiary Risks	None.
ADR/RID Substance Identification Number	CLASS 3 - 31(c)
CERCLA RQ	Cresol (100#)
Marine Pollutant	No.

15. REGULATORY INFORMATION

TSCA Listed	Yes
TSCA Exemptions	
WHMIS Classification	D.2.B B.3
MA Right To Know Law	All components have been checked for inclusion on the Massachusetts Substance List (MSL). Those components present at the de minimus concentration have been identified in the hazardous ingredients section of the MSDS.
California Proposition 65	This product does not contain materials which the State of California has found to cause cancer, birth defects or other reproductive harm.
SARA TITLE III-Section 311/312 Categorization (40 CFR 370)	Immediate, delayed, flammability hazard
SARA TITLE III-Section 313 (40 CFR 372)	This product does not contain a chemical which is listed in Section 313 at or above de minimis concentrations.

16. OTHER INFORMATION

NFPA Rating- FIRE	2
NFPA Rating- HEALTH	2
NFPA Rating- REACTIVITY	0
NFPA Rating- SPECIAL	None.
Revisions Highlighted	Flash Point (PMCC) (°C/F)

16. OTHER INFORMATION

Abbreviations

CAS#: Chemical Abstract Services Number
ACGIH: American Conference of Governmental Industrial Hygienists
OSHA: Occupational Safety and Health Administration
TLV: Threshold Limit Value
PEL: Permissible Exposure Limit
STEL: Short Term Exposure Limit
NTP: National Toxicology Program
IARC: International Agency for Research on Cancer
R: Risk
S: Safety
LD50: Lethal Dose 50%
LC50: Lethal Concentration 50%
BOD: Biological Oxygen Demand
Koc: Soil Organic Carbon Partition Coefficient.
TLm: Median Tolerance Limit

Disclaimer

The data contained herein is based on information that Shipley Company believes to be reliable, but no expressed or implied warranty is made with regard to the accuracy of such data or its suitability for a given situation. Such data relates only to the specific product described and not to such products in combination with any other product and no agent of Shipley Company is authorized to vary any of such data. Shipley Company and its agents disclaim all liability for any action taken or foregone on reliance upon such data.

Appendix G. Example Hood Sign In Sheet

Chemical Hood Sign In

Sign into hood before performing any work. Chemical buddy must sign in with you outside of normal business hours (8 AM - 6 PM, M-F). Resign into hood if returning more than an hour since last use.

Name	Date	Time	Chemical Used	Approximate Amount

Appendix H. CNF Approved Chemical Mixtures

The following solutions are allowed to be mixed at the CNF. This list does not cover every possible combination, but does cover the most common ones. Users should contact the Safety Manager with any questions regarding these mixtures or other possible combinations.

Ammonium Hydroxide, Hydrogen Peroxide
Hydrochloric Acid, Hydrogen Peroxide
Hydrochloric Acid, Nitric Acid (Aqua Regia)
Hydrofluoric Acid, Hydrochloric Acid
Phosphoric Acid, Sulfuric Acid
Hydrofluoric Acid, Nitric Acid (Polysilicon Etch)