CHEMICAL HYGIENE PLAN

Building: J.M. Patterson, #083

Room(s): 2225, Lab. for Advanced Materials Processing

Department: Materials Science and Engineering

Approved as UM Policy September 1994
Revised April 2002
Revised September 2004
Revised July 2006
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UM Policy on Occupational Exposure to Hazardous Chemicals in Laboratories

Approved by the President September 19, 1994

A. Purpose.

This is a statement of official University policy to establish the process for compliance with the Occupational Safety and Health Administration (OSHA) regulation "Occupational Exposure to Hazardous Chemicals in Laboratories."

B. Policy.

The University is dedicated to providing safe and healthful laboratory facilities for students and employees, and complying with federal and state occupational health and safety standards. Laboratory administrators, managers, faculty, staff and students all share responsibility for minimizing their exposure to hazardous chemical substances which, for purposes of this policy, shall be defined as chemicals which are carcinogens, toxic or highly toxic agents, reproductive toxins, irritants, corrosives, sensitizers, hepatotoxins, nephrotoxins, neurotoxins, agents which act on the hematopoietic systems, and agents which damage the lungs, skin, eyes, or mucous membranes.

The Chemical Hygiene Plan shall be implemented for all facilities at the University of Maryland, College Park, where hazardous chemicals are handled or used under all of the following conditions: (i) chemical manipulations are performed in containers designed to be easily and safely manipulated by one person; (ii) multiple chemical procedures or chemicals are used; and (iii) demonstrably effective laboratory practices and equipment are available and in common use to minimize the potential for employee exposure to hazardous chemicals.

The Chemical Hygiene Plan shall be reviewed and evaluated for its effectiveness at least annually, and updated as necessary.

C. Responsibilities.

1. Department of Environmental Safety shall:
   - (a) Appoint a Chemical Hygiene Officer to develop and coordinate administration of the UM Chemical Hygiene Plan (CHP);
   - (b) Prepare the CHP with annual review and revisions as needed;
   - (c) Distribute the CHP to each affected department for each Laboratory Supervisor or Principal Investigator (LS/PI);
   - (d) Provide consultation, worksite monitoring (sampling), advisory assistance and information concerning use of hazardous materials;
   - (e) Investigate, document and report to the BACH Committee, significant chemical exposure or contamination incidents;

(f) Collect and dispose of hazardous, radioactive and other regulated wastes;

(g) Direct periodic laboratory safety audits to determine regulatory compliance, and recommend action to correct conditions generating release of toxic chemicals;

(h) Provide training to all laboratory workers concerning:

(1) Provisions of the Chemical Hygiene Plan;

(2) Physical and health hazards of chemicals in the work area;

(3) Measures to protect employees from chemical hazards;

(4) Signs and symptoms associated with hazardous chemical exposure;

(5) Location of reference materials on the hazards, safe handling, storage and disposal of laboratory chemicals;

(6) The contents of the OSHA standard and its appendices;

(7) The permissible exposure limits (PELs) for OSHA regulated substances or recommended exposure limits if no PEL is listed; and

(8) The methods and observations used to detect the presence or release of a hazardous chemical.

2. Laboratory Supervisors/Principal Investigators (LS/PI) shall:

(a) Implement all provisions of the Chemical Hygiene Plan for laboratory facilities under their control;

(b) Develop and maintain a customized Chemical Hygiene Plan for laboratory operations under their control to include:

(1) Alphabetized inventory of all hazardous chemical substances,

(2) Written Standard Operating Procedures to address safety and health issues associated with work practices, protective equipment, in laboratory facilities under their control;

(3) Identification of occurrences or operations that may be encountered by laboratory employees and that require that the LS/PI be advised (prior approval).

(c) Prepare and implement laboratory-specific Standard Operating Procedures (SOPs) to include work practices, protective equipment, engineering controls, emergency procedures and waste disposal procedures;

(d) Demarcate and indicate on SOP all areas designated for the use of particularly hazardous chemicals (i.e., select carcinogens, reproductive toxins and acute toxins);

(e) Train laboratory workers regarding the specific practices and provisions contained in the laboratory SOP;

(f) Ensure that all lab employees have access to Material Safety Data Sheets for hazardous chemicals that are purchased or otherwise acquired for use in the lab facility;

(g) Ensure that all necessary personal protective equipment is available and used by lab employees;

(h) Notify the designated UM contact points when any of the University of Maryland prior notification conditions are anticipated;
(i) Comply with necessary documentation requirements; and
(j) Submit a current copy of their Chemical Hygiene Plan(s) including all required components to the Department of Environmental Safety and Departmental Compliance Officer.

3. Biological and Chemical Hygiene (BACH) Committee shall:

Review and approve all aspects of the Chemical Hygiene Plan and provide technical guidance for implementation of campus policy concerning chemical and biological safety.

4. University Health Center shall:
   (a) Coordinate and direct all required or recommended medical surveillance programs;
   (b) Provide medical consultations and examinations for laboratory workers who have been overexposed, or suspect overexposure, to hazardous chemical substances; and
   (c) Maintain medical records relating to consultations, examinations and medical surveillance as required by law.

5. Departmental and College Compliance Officers shall:
   (a) Assist Environmental Safety and laboratory supervisors with implementation of the Chemical Hygiene Program; and
   (b) Maintain current copies of Chemical Hygiene Plans.

6. Department Chairs and College Deans shall:
   (a) Require implementation of the Chemical Hygiene Program for affected laboratories under their control.

7. Individual Researchers and Laboratory Users shall:
   (a) Adhere to the requirements of the Chemical Hygiene Plan and SOPs;
   (b) Complete all safety training requirements and comply with documentation procedures;
   (c) Notify the PI/LM if any prior notification situations or occurrences are anticipated; and
   (d) Report all workplace injuries, chemical exposure incidents or unsafe conditions to their LS/PI as soon as possible.

D. Information

Assistance will be provided by the Department of Environmental Safety to any Department requesting guidance or training to satisfy implementation of this policy.

Emergency Telephone Numbers

UM Emergency (FIRE - POLICE - RESCUE) - 24 hour # 911

CALL IMMEDIATELY FOR ANY EMERGENCY INCLUDING INJURED OR SICK PERSON, CHEMICAL SPILL OR FIRE

Environmental Safety (Main Office) (301) 405-3960
(Industrial Hygiene, Hazardous Waste Management, Fire Protection, Hazard Communication, Safety Education)

Chemical Hygiene Officer (301) 405-3980
(Program Consultation and Administration)

Biological Safety (301) 405-3960
(Biological Safety, Regulated Pathogen Consultation)

Radiation Safety (301) 405-3985
(Health Physics, Radioactive Materials Procurement)

University Health Center Occupational Health (301) 314-8172
(Medical Consultation and Evaluation)

Workers' Compensation Office (301) 405-5466

Facilities Management Work Control (301) 405-2222
(Repair of Facility Equipment Deficiencies, e.g., fume hoods, emergency eyewashes, ventilation, etc.)

Laboratory Supervisor(s):	Business-hours #	After-hours #
Laurent Lecordier	Cell # (301) 602 9858, office (301) 405 5858, home (301)602 9858	
Gary Rubloff	Office # (301) 405 2949, (cell) 301 785 2751	

Laboratory Personnel:	Business-hours #	After-hours #
Erin Robertson(GRA), Office #(301) 405 2971, (cell) 919 345 5367		

Standard Operating Procedures (SOPs)

A comprehensive health and safety program should include documents that provide descriptions of standard methods or operations used within the facility. They should describe in clear and precise language the means and methods to be used by laboratory workers to minimize the risk of hazardous exposure while using hazardous chemicals.
These documents, commonly referred to as standard operating procedures (SOPs), should be followed by all laboratory employees.

The LS/PI is responsible for preparation of lab-specific SOP documents for attachment to the CHP. The LS/PI is responsible for determining the adequacy of the SOPs prepared. The lab-specific SOPs shall be incorporated in the on-site copy of the Chemical Hygiene Plan and placed in a designated location within the laboratory for immediate access by employees.

A good SOP is one that is clearly stated and realistic in scope. A laboratory LS/PI should prepare SOPs for all routine and repetitive operations as well as for general laboratory operations. The format of all SOPs should be consistent and should incorporate:

1. Facility name, department and section affected by or using the procedure;

2. Subject;

3. Issue date of the original document or current revision;

4. Any indication that revisions replace an earlier procedure;

6. Signature or initials of the SOP preparer as well as any reviewing authority; and

7. Concise instructions for safe and healthful performance of laboratory activities and procedures.

SOPs should indicate the measures that will be used to reduce or prevent employee exposure to hazardous chemicals, including engineering controls, hygiene practices. and the use and maintenance of personal protective equipment.

SOPs should include provisions for additional employee protection for work with particularly hazardous substances, including select carcinogens, reproductive toxins, and substances which have a high degree of acute toxicity. (See "Identification of Hazardous Materials, below.) Where appropriate, these additional measures should include:

1. Establishment of a designated area;

2. Use of containment devices such as fume hoods or glove boxes;

3. Procedures for safe removal of contaminated waste; and

4. Procedures for site and personal decontamination.

SOPs shall also indicate circumstances under which certain laboratory procedures, operations or activities require prior approval from the LS/PI before implementation (e.g., use of radioactive materials, bench top manipulation of volatile carcinogenic solvents without use of engineering controls, night or weekend work performed alone, reagent substitutions, etc.).

Examples of SOPs are available on the DES website at:

http://www.umd.edu/des/ls/index.html

Medical Consultation and Examinations

Employees who work with hazardous chemicals in the laboratory should be referred for medical consultation, examination, and/or surveillance (as appropriate to the circumstances) whenever:

1. An employee develops signs or symptoms associated with a hazardous chemical to which the employee may have been exposed in the laboratory;

2. An event takes place in the work area to create a likelihood of hazardous exposure; or

3. Exposure monitoring reveals an exposure level routinely above the action level (or in the absence of an action level, the Permissible Exposure Limit) for an OSHA-regulated substance for which there are exposure monitoring and medical surveillance requirements. (See "Exposure Monitoring" section, below.)

Examples of events or circumstances which might result in hazardous exposure include:

1. A spill or leak which rapidly releases a hazardous chemical in an uncontrolled manner;

2. Direct skin or eye contact with a hazardous chemical;

3. Symptoms such as headache, rash, nausea, tearing, irritation or redness of eyes, irritation of nose or throat, dizziness, loss of motor dexterity or judgement which disappear when the employee is removed from the exposure area and which reappear when the employee returns to working with the same hazardous chemical;

4. Two or more employees in the same laboratory work area exhibit similar symptoms; or

5. Exposure monitoring indicates exposures above regulated or recommended limits.

The University has established procedures for responding to job-related injuries. These procedures should be followed in the event of hazardous exposure due to the use of hazardous chemicals in the laboratory. Instructions and forms for reporting injuries and chemical exposures are available through the DES web page:

http://www.umd.edu/des/risk_comm/wcomp/

In the event of life-threatening injuries or illnesses, the UM Emergency Dispatcher should be immediately notified. All injury or illness occurring as a result of work activities should be reported to the Workers' Compensation Office, immediately after the incident occurs or the injury is treated. All incidents of hazardous exposure, including their disposition, should be reported to the Chemical Hygiene Officer.

The following information should be provided at the time that an employee is referred for medical consultation and/or examination:

1. Identity of the chemical(s) to which the employee may have been exposed;

2. Description of the conditions under which the exposure occurred, including any quantitative exposure data, if available; and

3. A description of the signs and symptoms of exposure that the employee experienced, if any.

A written report must be provided to the employer from any physician to whom the employee is referred for medical consultation or examination in connection with hazardous exposure. The physician's report(s) should indicate ONLY the specific findings of diagnoses related to occupational exposure and should include the following information:

1. Any recommendation for further medical follow-up;

2. The results of the medical examination and any associated test(s);

3. Any medical condition which may be revealed in the course of the examination which may place the employee at increased risk as a result of exposure to a hazardous workplace; and

4. A statement that the employee has been informed by the physician of the results of the consultation or medical examination and any medical condition that may require further examination or treatment.

As indicated above, all incidents of hazardous exposure (including disposition) should be reported to, and documented by, the Chemical Hygiene Officer (CHO). If no further assessment of the incident is deemed necessary, the reason for that decision should be included in the documentation. If the event is determined to require investigation, a formal exposure assessment will be initiated by the CHO. The purpose of an exposure assessment is not to determine whether there was a failure to follow proper procedures, but to identify the hazardous chemical(s) involved and determine whether an exposure might have caused harm to an employee. An exposure assessment may include the following items:

1. Interviews with the employee and complainant (if different);

2. Obtaining the following information:
   - the names of chemicals which may be involved
   - other chemicals used by the employee
   - all chemicals used by others in the immediate area
   - other chemicals stored in the immediate area
   - symptoms exhibited or claimed by the employee
   - comparison of symptoms with those referenced in the Material Safety Data Sheet for each involved chemical

- observation of control measures and personal protective equipment in use during the event
- notation of any on-site exposure monitoring performed previous to or during event

3. Monitoring or sampling the air in the area for suspect chemicals; and

4. Determination of whether the current control measures were adequate during the time of the incident.

Identification of Hazardous Materials

A hazardous chemical is defined by the OSHA laboratory standard as "a chemical for which there is statistically significant evidence based on at least one study conducted in accordance with established scientific principles that acute or chronic health effects may occur in exposed employees." Hazardous chemicals include carcinogens, toxic or highly toxic agents, reproductive toxins, irritants, corrosives, sensitizers, hepatotoxins, nephrotoxins, neurotoxins, agents which act on the hematopoietic system and agents which damage the lungs, skin, eyes or mucous membranes.

Laboratory supervisors have certain responsibilities for the management of these hazardous chemicals, including:

1. Inventory of all hazardous chemical substances which are used in their laboratories, and attaching the inventory to this CHP;

2. Maintenance of the labels on incoming containers of hazardous chemicals to ensure that they are not removed or defaced;

3. Maintenance of any Material Safety Data Sheets (MSDSs) that are received with incoming shipments of hazardous chemicals, and ensuring that the MSDSs are readily accessible to laboratory employees; and

4. Determination of whether chemical substances which are developed in the laboratory are hazardous chemicals within the definition of this CHP. If the chemical substance is a byproduct for which the composition is unknown, the substance should be deemed to be a hazardous chemical.

Laboratory supervisors also are responsible for identifying the following hazardous chemicals which are required to be used in an area specially designated for such use:

1. Select carcinogens: Any substance which meets one of the following criteria:

   - it is regulated by OSHA as a carcinogen;
   - it is listed under the category, "known to be carcinogens," in the Annual Report on Carcinogens published by the National Toxicology Program (latest edition);
   - it is listed under Group 1 ("carcinogenic to humans") by the International Agency for Research on Cancer (IARC) Monographs (latest edition); or
   - it is listed in either Group 2A or 2B by the IARC, or under the category, "reasonably anticipated to be carcinogens" by NTP, and causes statistically significant tumor incidence in experimental animals in accordance with criteria specified in the OSHA laboratory standard.

2. Reproductive toxins: Chemicals which affect the reproductive capabilities, including chemicals which are mutagenic and teratogenic;

3. Acute toxins; and

4. Unknowns: Chemicals which are synthesized in the laboratory and which are byproducts for which the composition is unknown.

Information concerning the health effects of chemical substances can be located in the following reference sources:

1. Material Safety Data Sheets (MSDS)

MSDSs are available through:
(A) The Department of Environmental Safety (DES):
1. Web Page (http://www.umd.edu/des),
2. Telephone (301-405-3960), or
3. After normal hours through UM Emergency Dispatcher at 911), and

(B) the vendor, manufacturer or distributor. (A MSDS must be provided at the time of initial purchase by the vendor, manufacturer or distributor without charge. A nominal fee may be assessed for additional copies.)

2. Registry of Toxic Effects of Chemical Substances (available through the DES Web Page:
(http://www.umd.edu/des/os/ccinfo/index.html)

3. National Toxicology Program (Chemistry Library or DES)

4. International Agency for Research on Cancer (Chemistry Library or DES)

5. DES maintains an Internet database of the Select Carcinogens as well as chemical substances that may be considered acute and reproductive toxins. This list may be accessed at:
www.umd.edu/des/ls

Use of any of the following materials may be subject to specific occupational safety and health standards as shown:

Asbestos, tremolite, anthophyllite and actinolite	29 CFR 1910.1001
4-Nitrobiphenyl	.1003
alpha-Naphthylamine	.1004
4,4'-Methylene bis(2-chloroaniline)	.1005
Methyl chloromethyl ether	.1006
3,3'-Dichlorobenzidine (and salts)	.1007
bis-Chloromethyl ether	.1008
beta-Naphthylamine	.1009
Benzidine	.1010

4-Aminodiphenyl	.1011
Ethyleneimine	.1012
beta-Propiolactone	.1013
2-Acetylaminofluorene	.1014
4-Dimethylaminoazobenzene	.1015
N-Nitrosodimethylamine	.1016
Vinyl Chloride	.1017
Arsenic (inorganic)	.1018
Lead	.1025
Cadmium	.1027
Benzene	.1028
Cotton dust	.1043
1,2-Dibromo-3-chloropropane	.1044
Acrylonitrile	.1045
Ethylene oxide	.1047
Formaldehyde	.1048
4,4'-Methylenedianiline	.1050
Methylene Chloride	.1052
Non-Asbestiform tremolite, anthophyllite and actinolite	.1101

These standards are not replaced by the Occupational Exposure to Hazardous Chemicals in Laboratories standard. Users of these materials are expected to adhere to the provisions of all applicable substance-specific standards if employee exposure routinely exceeds the OSHA-mandated permissible exposure limit (or Action Level, if specified). Copies of these standards may be obtained from the Department of Environmental Safety or through the OSHA website at:

www.osha.gov

Information and Training

All UM employees must assume an active role in maintaining a safe working environment by reporting any problems or noncompliance with policies to the LS/PI. All employees should fully utilize any information provided during formal and informal training sessions. Any staff member who does not understand a policy or procedure should consult the LS/PI, departmental safety committee or DES for clarification.

All employees shall be provided with information and training regarding the hazards of the chemicals in their work area. Employees shall be informed of:

1. The contents of the OSHA standard and its appendices;

2. The location and availability of the CHP;

3. The permissible exposure limits (PELs) for OSHA regulated substances or recommended exposure limits if no PEL is listed;

4. The methods and observations used to detect the presence or release of a hazardous chemical;

5. The physical and health hazards of chemicals in the work area;

6. The measures employees can take to protect themselves from chemical hazards, including specific procedures (SOPs) to be used;

7. Signs and symptoms associated with exposures to hazardous chemicals used in the laboratory; and

8. The location of known reference material on the hazards, safe handling, storage, and disposal of chemicals found in the laboratory.

Distribution of training materials to LS/PIs and members of departmental safety committees is coordinated through the Department of Environmental Safety. Training of laboratory workers in general laboratory safety and the provisions of the OSHA laboratory standard's requirements shall be conducted by UM Chemical Hygiene Officer (or designee) during training sessions scheduled through the Department of Environmental Safety or through special arrangement with DES. An on-line Chemical Hygiene training course is also available to UM laboratory employees at the following website:

http://des.umd.edu/TrainingClass/index.cfm

The LS/PI shall be responsible for training of all supervised laboratory employees as to specific operations, safety equipment, emergency procedures, SOPs and chemical use which apply to the laboratory facilities. Documentation of general laboratory safety and CHP training conducted by the Department of Environmental Safety shall be maintained within each department and by the Department of Personnel Services as part of the employee's permanent record. Documentation of laboratory-specific training provided by the LS/PI shall be maintained within each department and laboratory.

Exposure Monitoring

OSHA has established "Permissible Exposure Limits" (PELs) for laboratory employees' exposures to certain regulated substances. Exposure levels must be determined and monitored under certain circumstances. A medical surveillance program has been established for certain specified employees whose work assignments involve regular and frequent handling of toxicologically significant quantities of a chemical. In addition, the Department of Environmental Safety is responsible for making determinations regarding the requirements for area and/or personal exposure monitoring in specific circumstances.

PELs are specified in the OSHA regulation 29 CFR 1910, Subpart Z Toxic and Hazardous Substances. In addition, PELs are usually indicated on the MSDSs, and can be obtained from the Department of Environmental Safety.

These limits are defined as:

- Eight-hour time weighted average (TWA)
  The average concentration to which an employee may be exposed to a particular chemical for up to eight hours per day, five days per week.
- Short Term Exposure Limit (STEL)
  The average concentration to which an employee may be exposed to a particular chemical for up to fifteen minutes per day.
- Ceiling (C)
  The maximum concentration to which an employee may be exposed to a particular chemical at any time.

Often, a notation of "Skin" is printed with an exposure limit. This indicates that skin absorption of that chemical occurs readily which would contribute to an employee's overall exposure. Employee exposure to dermal absorption of chemical substances can often be monitored through the use of biological testing.

Employee exposure should be monitored in the following circumstances:

1. Initially, where there is reason to believe that exposure levels to any chemical substance regulated by a standard routinely exceed the action level (or in the absence of an action level, the PEL) for an OSHA-regulated substance for which there are exposure monitoring and medical surveillance requirements; and

2. Periodically, where the initial monitoring discloses employee exposure over the action level (or in absence of an action level, the PEL).

The general training provided by the Department of Environmental Safety will include information regarding the identification of situations where employee exposure might exceed the PEL, TLV or STEL. TLVs (Threshold Limit Values) are eight-hour time-weighted average inhalation exposure limits recommended by the American Conference of Governmental Industrial Hygienists. The Department of Environmental Safety will perform area and/or personal exposure monitoring at the request of any LS/PI or laboratory worker. The employee will be provided written notification of monitoring results, within 15 working days after receipt of monitoring results by the University.

Where initial monitoring discloses employee exposure over the action level (or in the absence of an action level, the PEL), the affected employee must be provided with personal protective equipment, unless engineering controls are available as a feasible means of controlling exposure. The LS/PI is responsible for ensuring that appropriate protective equipment is available to laboratory employees.

Monitoring will be terminated when appropriate in accordance with the relevant standard.

Prior Approvals

The Principal Investigators/Laboratory Supervisors (LS/PI) is responsible for providing institutional notifications as defined below:

1. Any purchase, possession or use of explosive materials (as defined by the US Department of Alcohol, Tobacco & Firearms) must be approved by the UM Fire Marshal (301-405-3970). A comprehensive list of explosive materials may be accessed from the ATF Website at:
   http://www.atf.treas.gov/pub/fire-explo_pub/listofexp.htm

2. Any modification to a chemical fume hood or other laboratory local exhaust system must be reviewed and approved by the Department of Facilities Management (301-405-0255) and/or the Department of Environmental Safety (405-3960) before it may be used as a means to control exposure to hazardous materials.

3. Any use of hazardous chemicals that may present a hazardous condition due to inadequate ventilation must be reviewed and approved by the Chemical Hygiene Officer prior to initiation of the operation.

4. Any research involving animals must be reviewed and approved by the Institutional Animal Care and Use Committee. Additional information is available at the following Website:
   http://www.umresearch.umd.edu/IACUC/

5. Any possession or use of radioactive materials or radiation-producing devices must be reviewed and approved by the Radiation Safety Officer. Additional information may be obtained by calling (301) 405-3985.

6. Any research work involving human subjects must be reviewed and approved by the Institutional Review Board. Additional information is available at the following Website:
   www.umresearch.umd.edu/IRB

7. Any purchase, possession or use of etiologic agents must be reviewed and approved by the UM Biosafety Officer. Additional information may be obtained by calling (301) 405-3975 or from the following website:
   http://www.umd.edu/des/biosafety/infectious/index.html

8. Treatment (e.g., neutralization) or drain disposal of any hazardous waste must be reviewed and approved by the Environmental Affairs section of the Department of Environmental Safety. Additional information may be obtained by calling (301) 405-3163.

9. Any use of respirators must be reviewed and approved by the UM Respiratory Protection Program Administrator. Additional information may be obtained by calling (301) 405-3980 or from the following website:
http://www.umd.edu/des/os/respirator/index.html

10. The use of extremely toxic gases must be reviewed and approved by the Chemical Hygiene Officer prior to initiation of work. These gases include:
    - Arsine and gaseous derivatives
    - Chloropicrin in gas mixtures
    - Cyanogen chloride
    - Cyanogen
    - Diborane
    - Germane
    - Hexaethyltetraphosphate
    - Hydrogen cyanide
    - Hydrogen selenide
    - Nitric oxide
    - Nitrogen dioxide
    - Nitrogen Tetroxide
    - Phosgene
    - Phosphine

Laboratory employees are responsible for obtaining approval from the LS/PI if any of the following operations will occur:

1. Laboratory operations that will be left unattended.

2. Modification of any established laboratory procedure.

3. Modification to laboratory chemical inventory.

4. Continuation of any laboratory procedure if unexpected results occur.

5. Use of Particularly Hazardous Materials in locations where no engineering controls (e.g., fume hood) are to be used.

6. Any operation for which employees are not aware of the hazards nor are confident in their ability to be adequately protected.

The LS/PI is also required to evaluate these specific laboratory operations and include in Appendix II any additional conditions that require prior approval.

Laboratory Safety Guide and References

The Laboratory Safety Guide is a separate document prepared and distributed by the Department of Environmental Safety which is available on-line at:

http://www.umd.edu/des/ls/index.html

The Guide was assembled to assist laboratory supervisors and workers in their daily operations at UM and to provide a means to lessen employee exposure to hazardous materials and operations. It can supply much of the information needed to provide laboratory workers a safe working environment. However, laboratory workers should not assume that this guide will supply sufficient information to prevent injury and protect the environment. The nature of the work that is performed in many research and testing laboratories increases the necessity for safety planning and awareness. The Principal Investigator and other faculty often have special expertise in the unique or specific experimental processes used in laboratories under their control, and the prepared SOP may supersede general laboratory safety guidelines.

Recommended reference sources concerning safe operations in laboratories include:

CRC Handbook of Laboratory Safety

CRC Press, Inc.

Guide for Safety in the Chemical Laboratory

Van Nostrand Reinhold Company

Improving Safety in the Chemical Laboratory

John Wiley and Sons

Prudent Practices for Handling Hazardous Chemicals in Laboratories

National Academy Press

Safe Storage of Laboratory Chemicals

John Wiley and Sons

Safety in Academic Chemistry Laboratories

American Chemical Society

Appendix I

X-7.00(A) UM POLICY CONCERNING FIRE EMERGENCIES APPROVED BY THE PRESIDENT MARCH 6, 1993

A. Purpose. This is a statement of official University policy for the reporting of fire emergencies and for the evacuation of campus buildings during fire emergencies, in compliance with local, state, and federal regulations.

B. Policy. A fire emergency exists whenever:

1. A building fire evacuation alarm is sounding;

2. An uncontrolled fire or imminent fire hazard occurs in any building or area of the campus;

3. There is the presence of smoke, or the odor of burning;

4. There is spontaneous or abnormal heating of any material, an uncontrolled release of combustible or toxic gas or other material, or a flammable liquid spill.

C. Procedures. Campus Buildings shall be immediately and totally evacuated whenever the building evacuation alarm is sounding.

1. Upon discovery of evidence that a fire emergency exists, an individual shall accomplish, or cause to be accomplished, the following actions:
   (a) SOUND AN ALARM. Activate the building fire alarm in buildings equipped with a manual fire alarm system. Shout a warning and knock on doors as you evacuate in buildings not equipped with a fire alarm.
   (b) SHUT OFF ALL MACHINERY AND EQUIPMENT IN YOUR AREA.
   (c) LEAVE THE BUILDING AT ONCE.
   (d) CALL THE FIRE DEPARTMENT FROM A SAFE PLACE.
      (1) On-Campus phones DIAL 911
      (2) Off-Campus phones and campus pay phones DIAL 911
      (3) Use Campus emergency phones;
      Indoors - Yellow wall phones with red "EMERGENCY" markings (some corridors)
      Outdoors - Yellow phone boxes with red "EMERGENCY" markings, under blue lights.
      (4) When the emergency operator answers, ask for the fire department, give as much specific information as possible. State that you are from UM~~CP~~ and include the proper name of the building and room number, floor, or other specific area. Do not hang up until released by the dispatcher. A PHONE CALL MUST BE MADE! ALL BUILDING FIRE ALARMS DO NOT NOTIFY THE FIRE DEPARTMENT.
   (e) MEET THE FIRE DEPARTMENT OUTSIDE AND DIRECT THEM TO THE EMERGENCY.
   (f) ALL FIRES, EVEN IF EXTINGUISHED OR FOUND EXTINGUISHED, MUST BE REPORTED.
   (g) ALL FIRE ALARMS, EVEN IF SUSPECTED TO BE FALSE OR ACCIDENTAL, MUST BE REPORTED TO THE FIRE DEPARTMENT.

2. The evacuation procedures shall be as follows:
   (a) It shall be the responsibility of every person to immediately leave a University building whenever the fire alarm is activated or a fire emergency exists.
   All students, faculty, and staff are required to leave the building and remain outside until the emergency is over. No one shall restrict or impede the evacuation.

(b) Department heads are expected to review annually fire prevention and fire survival information with faculty and staff, or to schedule such a presentation with the Department of Environmental Safety. Such information is available from the Department for use and distribution.

3. Whenever it is brought to the attention of the staff of residential buildings, or departmental personnel, that the fire alarm or sprinkler system is inoperable or has been placed out of service, a firewatch shall be established.
   (a) Responsible personnel (residential staff, safety committee, etc.) shall be assigned to the firewatch.
   (b) The entire building shall be toured at least one time during each hour of the firewatch.
   (c) The emergency dispatcher (405-3555) shall be notified each hour that the watch has been performed.
   (d) The firewatch shall be maintained at all times that the building is occupied until the fire protection system is repaired.

4. INTERRUPTION OF FIRE ALARM:
   (a) No person may shut off any fire protection or alarm system during a fire emergency incident without the permission of the fire department officer in charge.
   (b) No person may shut off any fire protection or alarm system during a bomb threat emergency without the permission of the police officer in charge.
   (c) It shall be the responsibility of the Department of Facilities Management Department to reset or repair any fire protection or alarm system after an emergency incident when notified by the fire or police department in charge. The Department of Facilities Management shall inspect each such system immediately after every emergency incident and place the system in serviceable condition.
   (d) The fire and police departments may reset an alarm system only if there is no damage to the system and when it is within their technical capabilities to do so.
   (e) Any person desiring to interrupt service to any fire protection or alarm system must obtain permission from the Department of Facilities Management, Work Control Center (405-2222) which shall notify the fire and police departments of every such interruption.
   (f) Fire or police department must request the Facilities Management to repair or rest a fire protection system, via the Work Control Center (405-2222).

5. INFORMATION RELEASE TO MEDIA AND THE PUBLIC:
   All information regarding University fires will be released through the Department of Environmental Safety in cooperation with the Public Information Office. No other University agency or employee may release official statements regarding the cause, origin, or nature of campus fires.

D. Information

Assistance will be provided by the Department of Environmental Safety to any Department requiring help and advice in its implementation of this UM policy.

Appendix II

Prior Approval Criteria

The LS/PI shall indicate any circumstances under which a particular laboratory operation, procedure or activity shall require prior approval from the LS/PI (or designee) before implementation. If no circumstances are identified, the LS/PI shall write "none" in the first provided space. Additional pages may be added as determined necessary by the LS/PI.

1. Circumstance: Introduction of any new chemicals (solid, liquid or gas) not listed on the lab chemicals inventory. To be approved by the lab manager, the requester will have to supply all necessary documents for safe operation, including Materials Safety Data Sheets and Standard Operating Procedure if needed.

   Prior approval to be obtained from: Lab manager

2. Circumstance: Installation/removal of any new piece of equipment.

   Prior approval to be obtained from:_Lab manager

3. Circumstance: Repair of lab equipment. Notice: no lab users are allowed to perform electrical work involving voltages above 24V.

   Prior approval to be obtained from:_Lab manager

4. Circumstance: Installation / replacement of gas cylinders.
_____

Prior approval to be obtained from: Lab manager

5. Circumstance: “Plumbing” work on existing gas supply lines. Opening any gas line in LAMP is strictly forbidden in the absence of the lab manager.

Prior approval to be obtained from: Lab manager

6. Circumstance: Maintenance of process vacuum pumps. Opening a pump for maintenance (e.g., oil change) can present serious hazards due to the potential presence of the residual toxic gases.

Prior approval to be obtained from: Lab manager

7. Circumstance: _____

_____

_____

_____

Prior approval to be obtained from:_____

Appendix III

Standard Operating Procedures

(to be attached by Laboratory Supervisor)

Notice: Standard Operating Procedures are listed on the LAMP website at
http://www.enma.umd.edu/LAMP/lamp_SOPs.htm

These documents include:

- LAMP general operating procedure and guidelines is a 51 slide power point document providing general guidelines and procedures when working in LAMP. It reviews LAMP access procedure, operating hours, personal protective equipment requirements, work with chemicals, chemical waste management, authorization for use of equipment, general safety and emergency procedures.
- LAMP SOP for process gases is a 17 pages pdf document that provides a review of safety features and emergency procedures related to the use of semiconductor process gases in LAMP. It details gas detection units, sensor integration and alarm protocols, procedures to install or replace gas cylinders.
- LAMP emergency table is a one page pdg file that summarizes the types of safety and gas detection sensors, their locations, the associated alarm protocol and the procedure to disengage these alarms.
- Hydrofluoric acid SOP
- Piranha solution SOP
- PZT sol gel materials SOP
- Handling of tungsten hexafluoride WF6 gas manifold SOP
- MAS 400 mask aligner SOP
- Automated four point probe station SOP

A printout of all these SOPs is located in LAMP, in the Chemical Hygiene Plan binder located on the access door to the clean room.

Lab users must follow safety guidelines listed on LAMP website at
http://www.enma.umd.edu/LAMP/safety.htm

Standard Operating Procedure #1
LAMP General safety guidelines

Facility: Laboratory for Advanced Materials Processing
2225 JM Patterson bldg, Materials Science and Engineering
University of Maryland, College Park MD 20742
(301) 405 7250

Lab Director: Gary Rubloff
2145 AV Williams Bldg
(301) 405 2949

Lab Manager: Laurent Lecordier
2147 AV Williams Bldg
(301) 405 5858, cell (301) 602 9858

Scope: This SOP reviews the general safety issues related to the work in LAMP as well as emergency procedures and chemicals handling and disposal.

This SOP is adapted from the content of the safety guidelines on the LAMP website at http://www.enma.umd.edu/LAMP

Last revision: 09/08/04 by Laurent Lecordier

Safety is paramount in LAMP. Due to the nature of semiconductor and microsystems processing, activities within LAMP must be undertaken with extreme care and a full understanding of all proper safety procedures. Violations of safety protocols will result in temporary expulsion from the lab. Permanent expulsion will result from gross negligence of the safety rules. This can mean serious delays or even the end of your thesis. You have been warned!

Outline of the LAMP safety reference guide

1- Before you begin: link to safety overview documents: general concepts about chemical handling, storage and disposal
2- "The 10 Commandments of LAMP"
3- General rules of operation for the LAMP cleanroom: rules that must be followed by any user of the clean-room facility
4- Safety policy
5- Emergency procedures
6- Chemicals safety issues
7- Gas safety issues

There are several important online safety resources you must be aware of:

- The University of Maryland Department of Environmental Safety (DES)
- Online Material Safety Data Sheets (MSDS) from the University of Maryland website and our MSDS web page where you can retrieve MSDS for the chemicals used in LAMP.

This guide is intended to help in understanding proper chemical handling and basic cleanroom safety issues. It also present important issues related to the use of hazardous gases in LAMP.

Every user of the LAMP facility must take the following training:

- Take the DES New Laboratory Researcher Training course - required training for all new laboratory research personnel, including information on applicable regulations and guidelines, recommended work practices, selection of personal protective equipment, and proper disposal of hazardous chemicals and biological waste. This training is offered every month.
- Take the DES Chemical Hygiene Training course - All personnel who work with chemicals in laboratories are required to have Chemical Hygiene Training. For your convenience, this training class is offered on-line (see the DES web page).
- Read carefully this LAMP Safety Reference Guide , the safety overview document and the LAMP general operating procedures and guidelines.
- Pass the LAMP safety quiz.
- It is also strongly recommended to attend the Safety workshop offered annually at the start of the fall semester by DES, as well as to take the on-line training for Hazardous Waste Management.

1. Before you begin:

Carefully read the safety overview document . This guide offers general safety notes when working in a clean room, especially about chemical handling and storage.

2. The "10 Commandments of LAMP"

- Safety is non negotiable. Safety must be your primary concern at all time.
- Be proactive about safety. If you see a safety hazard, you are responsible to report it to the lab manager even if it implies other users of the lab. Each person have the right to question a procedure that he/she considers inherently unsafe.
- Never leave the lab without cleaning or in unsafe conditions
- If you break something, you must report it. Occasional accidents are understandable and forgivable. Secrets or continuing mal practice are not acceptable
- Never assume that other users are knowledgeable about your activities. Make sure to clearly label or mark any recipient, chemical solution, source of potential hazard... you leave unattended (even for a few minutes).
- Each user must take responsibilities in the training and organization of the lab. It is everyone's responsibility to maintain LAMP in order. If you see something wrong, do not assume somebody else will fix it for you.
- Learn from your colleagues and teach them in return.
- Document your activities or problems in the log books put at your disposition in LAMP.
- Report ideas to improve work in LAMP
- Most of all, respect other people's work. Your work is valuable so is other people's work! Be clean, be safe, be considerate and professional.

3. General rules of operation for the LAMP

(adopted from the Cornell CNF, CAMD & Micralyne) :

In this section, you will find general rules that must be known and applied by any users of the LAMP facility. More details regarding chemicals and gas handling can be found in the section 5 and 6 of this guide.

- Dress code and general issues
  - Inside the cleanroom clothing, shoe covers, Tyvek coat (or bunny suit if you are wearing a short or skirt), hair net must be worn at all time.
  - Gloves and safety glasses must be worn all the time when you are in the cleanroom, no matter what you are doing.
  - No Sandals and open-toed shoes.
  - Smoking, food, drinks, chewing-gum are **prohibited** anywhere in the LAMP facility (cleanroom and pre-cleanroom). They all are huge sources of dust and can present serious safety risks.
  - Torn or dirty coats and shoe covers must be discarded after use. Hair nets are not to be reused.
  - It is not allowed to leave the facility wearing the garments

- Use of equipment
  - Non-authorized users are not allowed to work on any of the cleanroom equipment. To be authorized to work on a specific piece of equipment, you must imperatively contact the tool supervisor in charge (see LAMP Management Team)

- General storage
  - Because cleanroom space is a premium, make sure to follow these rules or your items will be discarded without notice.
  - Tools, samples and other small belongings can only be stored in the yellow plastic boxes that have been allocated to your group and stored on the metallic shelves in the cleanroom. If you need additional storage space inside the cleanroom, you must contact the LAMP manager.
  - Additional storage space is also available in the LAMP annex (room 2229). As in the cleanroom, specific spaces have been allocated to each group. All items there must be labeled with name, date and phone extension or they will be taken out of the annex.

- Chemicals storage
  For safety concerns, chemicals inventory is managed by a student supervisor (see LAMP management). He will make sure that all the Materials Safety Data Sheets and product inventory are up to date.
  You must get the approval of the lab manager or the student in charge of the chemical inventory before importing any new chemicals in the LAMP facility.
  The chemicals inventory is divided into 2 main categories:
  - chemicals for general use that are shared by all the groups (i.e. acetone, methanol, DI water, nitrogen gas...). The supervisor in charge of the chemicals will manage the supply of these chemicals. You are welcome to contact him if re-supply is necessary.
  - chemicals that are used specifically by a research group.

  After pre-approval, chemicals brought to LAMP must be very clearly labeled with the name of chemicals, the date of introduction and the user name. Make sure they are stored safely in the designated area.

- Wet processes and other work in LAMP
  - Never use specific chemicals, glassware or other equipment that are used and labeled by another group.
  - Always clean up your work area before you leave. Thoroughly rinse the beakers you used with DI water and then store upside-down in their appropriate locations.
  - Wash thoroughly any chemical bottle you used. Use cleanroom wipes to dry and then store in the appropriate cabinet.

- Label all the glassware or fluoroware you are using and specify the contents, your name and the date. If you have to leave the area for a little while, let people know what you are doing in the cleanroom and what chemicals are in the beakers. This also goes for any processing that needs to be carried out over night or more (leave a written note at the work station indicating your return time, a contact name and phone number).

- Chemicals disposal
  - All disposed items have to be labeled with the name(s) of chemical(s), the date of disposal and the name of user. If you use recyclable bottle, make sure you remove or scratch away old label.
  - Thoroughly rinse empty chemical bottles with regular tap water. Fill and dump at least 3 times. Put a scratch through the original label and mark it with "WASHED BOTTLE" and place in the designated area beneath the eye wash station.
  - No unauthorized solutions
  - No unlabeled solutions
  - No chemicals in waste baskets
  - No unwashed bottles in waste baskets
  - Never touch exposed skin with your gloves, avoid transfer of oils to the glove surface.

The above rules are essential for maintaining normal cleanroom operation. Any one violating the rules will be subject to a warning, suspension of access to cleanroom for one month, or loss of privilege to work in the cleanroom altogether.

Short and Simple Consequences: You can lose access to the LAMP facility if you violate any safety rule or cause injury or damage to persons or equipment.

4. Safety Policy

All LAMP users are encouraged to report all incidents, near misses, and unsafe acts they encounter while working at the lab. It **is not intended** to criticize or 'pick on' any person. By reporting these incidents, corrective actions may be recommended to prevent similar or more catastrophic incidents from happening. "Incident Report" forms are available in the cleanroom. Notify the lab manager by sending an e-mail.

Incident Report	
Date:	Name:
Report:	

5. Emergency Procedures

5.1 Emergency procedure resulting from the leak of silane (see gas safety issues)

As in most semiconductor research facilities, LAMP houses a variety of hazardous gases. Therefore it is equipped with an integrated alarm system that includes a MDA System 16 gas detector (located in front of the middle door in the hallway). This system can detect traces of

silane, a highly ignitive gas, at concentration as low as 2 ppm in four different locations of the LAMP facility. It also integrate other sensors (HF, H2, overpressure, overflow...) to provide an appropriate alarm response. If a positive detection occurs, the MDA system 16 will automatically activate the J.M. Patterson building alarm and notify the UM police department. 2 red flash lights inside LAMP will also be triggered.

In case of such an alarm, anyone present in the lab must:

1. Evacuate the LAMP facility IMMEDIATELY.

2. If the building alarm is not already sounding, pull the manual emergency station located in the hallway for general evacuation of the building.

3. Call 911 to confirm that they have been notified by the automated supervisory unit.

4. Call the lab director (Gary Rubloff @ 301 405 2949) and Laurent Henn-Lecordier @ 301 602 9858 (cell) or 55858 (office).

The LAMP facility is equipped with an emergency push button located to the left of the main entrance door that can be activated manually. By pushing this button, the J.M. Patterson building alarm will be triggered and the UM police department automatically notified.

Please make sure to review the paragraph related to Gas safety issues.

5-2 General emergency procedure

- **In case of fire**

  Pull fire alarm and follow evacuation procedures
  Notify LAMP staff

- **Injuries**

  All injuries should be immediately reported to the LAMP staff
  All users are expected to cease work to assist an injured user.
  If large chemical exposure is involved, another user must accompany the injured person to the hospital emergency.
  If deemed necessary, phone 911 and request an ambulance to be sent to the J.M. Patterson bldg (083), room 2225
  An incident report must be completed ("Incident Report")

- **Chemical Spills and Exposure**

  In the event of chemical spill, first ensure that all injuries are being treated. If chemical exposure (skin, eyes, etc.) has occurred, immediately get to a source of water, remove contaminated clothing, and flush the contaminated area thoroughly for at least 15 minutes. Then, depending on the size of the spill, do one of the following:

  1. If the **spill is small enough**, then qualified personal may clean it up themselves at their discretion. The incident must be reported ("Incident Report").

  2. If you feel that the **spill is large enough** to warrant LAMP staff response:

     - Evacuate the immediate area.

- Clearly mark the area to prevent other users from accidentally entering the spill area. If there are no sufficient tools for marking the area, recruit another user to stand as a "lookout" near any ingress route until LAMP staff (or qualified persons) arrive.

- Show LAMP staff the exact area of the spill and the **nature of the spill**

- Fill out the incident report form ("Incident Report").

- If at any time a spill is deemed to be a serious hazard to other building personnel (due to size, fire, toxic threat), pull a fire alarm to evacuate the building.

NB: Make sure that you are aware of the locations of eye wash station and emergency shower before working with hazardous chemicals.

6. Chemical Safety Issues

- **Authorization**

  Only persons who have been trained to handle chemicals at LAMP may use chemicals in the facility.

- **Material Safety Data Sheets**

  MSDS sheets for each chemical we use at LAMP are available (MSDS sheet binder) in the cleanroom area or online for download. If importing a new chemical into the facility, MSDS sheets need to be obtained before purchasing the product. (Link for Online MSDS info).

- **Wet processing areas**

  All the wet etch processes that have been approved by the lab Manager should be done in the wet deck.

- **Working with etch solutions requires a "Buddy system"**

  While working with or preparing chemical etches and baths, another user (Buddy System) must be within range of verbal contact for the purpose of immediate emergency response. For solutions containing HF, another user who has been approved to work with HF, **must be in the room**.

- **Importing chemical into LAMP**

No chemical may be brought on-site without prior approval by the manager. The lab manager and the user must determine the safety concerns associated with the chemical (if any) and develop procedures for safely working with this chemical.

- **Developing new wet processing recipes**

  There are inherent dangers when developing new etch recipes. Chemical can react in unexpected ways that can create dangerous situations (causing injury, death to users and damage to equipment). If a new process is needed, you must abide by the following procedures:

  1. If the recipe is significantly different than those used previously in the lab, the lab manager must be informed (verbally). You need this approval for any significant recipe modifications.

2. Before mixing any chemicals, it is your responsibility to look into any reactions that might take place (intentionally or by accident).

3. When you first mix the new recipe, use first small volumes (<50 ml) of solutions or additives. This will ensure that if the chemicals react in unforeseen ways, the possible explosions or gas releases are small.

- **Chemicals: Storage and Handling**
  - a-***Storage***

Table 1 below lists some of the more common chemicals used in the lab and their concentrations. Many of these chemicals can cause severe damage to human tissue and life. Therefore, you must be alert and cautious when using these chemicals to avoid all "direct" contact with them. The risk of injury will be minimized if the safety procedures are followed. Acids, bases, and solvents must be stored in separate marked cupboards.

Chemical Type	Chemical name	Formula	Concentration
Acids and Oxidizers	**Hydrofluoric Acid**	HF	49%
	Hydrochloric Acid	HCl	36%
	Nitric Acid HNO3	HNO3	68%
	Sulfuric Acid H2SO4	H2SO4	96%
	Hydrogen Peroxide	H2O2	30%
Bases	**Potassium Hydroxide**	KOH	45%

Solvents	2-propanol	CH3CHOHCH3	100%
	Acetone	CH3COCH3	100%
	Methanol	CH3OH	100%

Table1: Concentration of common chemicals in the microfab

- **b-Handling**

1. Users who handle hydrofluoric acid or HF-containing solutions (BOE) must be authorized by the lab manager prior to handle these chemicals.
2. Know which chemicals and containers are compatible. Some chemicals or mixtures can not be used in plastic (hot Piranha) or in glass (HF).
3. Always work with chemicals under **fumehood**.
4. Heavy-duty rubber **gloves**, **chemical apron** and a **face shield** must be worn when handling hazardous chemicals.
5. When mixing chemicals, use only one bottle at a time. Do not open a new bottle unless an existing bottle is completely empty. Pour the chemical slowly. Do not let it gulp. Remember the triple A rule: **Always Add Acid to water** never do the reverse. This prevent violent splashing.
6. DO NOT mix organic solvent with inorganic chemicals. This can result in violent reaction or explosion.
7. Never work with acids and bases side by side because violent reactions can occur.
8. DO NOT pour chemicals back into the storage bottle. If you pour too much, dispose of it appropriately.
9. Put the cup back on each chemical bottle securely.
10. **Be Cautious all times !!**. Because most chemicals used in the lab look like water, always assume any liquid is dangerous if not labeled.
11. Table 2 lists some of the flammable chemicals encountered in the cleanroom.
12. When using hot-plates, check that your beaker is both suitable for hot plate use and smaller than the area of the plate.
13. Always monitor the temperature of the chemicals on a hot-plate with a Teflon coated thermometer.
14. Rinse the heavy chemical gloves with DI water before you take them off.

15. Never touch your skin (face) with your gloves on.

16. A fire extinguisher is located outside the cleanroom. The eye wash station and emergency shower are located in the cleanroom..

17. Hydrofluoric acid (HF) is more dangerous than it seems. Because HF does not hurt when it makes contact with skin, people get careless. READ carefully the Standard Operating Procedure related to hydrofluoric acid prior to any work involving this chemical. Calcium Gluconate Gel is available to treat HF burns. You will find it in the First Aid Kit located next to the lab entrance door.

- **Chemicals: Waste Disposal**

Contact the student in charge of waste disposal. For general information on Hazardous and regulated waste procedures, please check the DES website.

Please be aware that the disposal of hazardous waste down drains, sinks, etc. is prohibited.

1. Waste Containers
   - Hazardous waste must be collected in containers that are compatible with the waste.
   - Keep all hazardous waste containers closed at all times unless you are adding or removing waste.
   - Label each container of hazardous waste with the UM Hazardous Waste Green Tag when you first place waste into a container.
   - Do Not store incompatible waste containers side by side
   - You may use a washed bottle as a waste container. Make sure you wash it thoroughly to remove all the previous chemicals and scratch away the original label.

2. Waste Pickup
   - Request Waste Pickup system via the DES web page.
   - You must take the online Hazardous waste generator training before submitting any waste pickup request.

3. Unknown or Unlabeled waste

Please be aware that:
- It is the responsibility of each individual generator and department to properly label hazardous materials and identify containers of hazardous waste at the time accumulation begins.
- DES will identify, remove, and dispose of unknown wastes for on-campus waste generators. However, the generator or generating department will incur a $110.00 per bottle fee for all solid and liquid unknown wastes.
- DES will also arrange for a contractor to sample, analyze, and dispose of any unknown cylinders. The generator or generating department will incur
  the full costs of the contractor's services, which can exceed $2,000.00 per cylinder.

4. Procedure for HF disposal

HF is a very Hazardous chemical. Any person who uses it must receive a special training and authorization. The binding of free fluorine ions with Calcium has been recommended for HF neutralization. Calcium chloride can be used to neutralize HF in 6 parts to 1 part of HF.

- Small amount of HF (<75 ml) can be poured down the drain as long as it is neutralized (with CaCl2) and diluted with large amount of water.
- While neutralizing the HF solution, DO NOT add the two reactants together directly. The **reaction** will be reasonable **vigorous** and **toxic gas** may be released.

- You must know that BOE is not a dilute HF. The ratio given on the BOE container is buffer to HF, so the fluorine content is the same as in HF for any ratio. For this reason, the same amount of Calcium Chloride must be used when neutralizing BOE as when neutralizing HF.
- Large amounts of HF solutions (>75ml) must be collected in a plastic container, properly labeled as a hazardous waste.
- Do not completely fill up the waste container with HF solution.
- Store the waste container in the designed safe area.
- Call for waste pick up

5. Piranha Hazards

A piranha is used to remove organic residues from substrates. Two different solutions are used. The most common is the acid piranha: a 3:1 mixture of concentrated sulfuric acid (H_2SO_4) with hydrogen peroxide (H_2O_2). Also used is the base piranha: a 3:1 mixture of ammonium hydroxide (NH_4OH) with hydrogen peroxide (H_2O_2). Both are equally dangerous when hot, although the reaction in the acid piranha is self-starting whereas the base piranha must be heated to 60 degrees before the reaction takes off.
There are many things which will cause the reaction to accelerate out of control. "Out of control" can mean anything from the piranha foaming out of its bin and on the deck, to an explosion with a huge shock wave including glove and acid-gown shredding glass sharps. Piranhas burn organic compounds. If you provide sufficient fuel for them (i.e. photoresist, IPA), they will generate enormous quantities of heat and gas.

Important safety notes:

- Never store piranha. Leave it in an open container until completely cool. Then aspirate the cool solution. A piranha stored in a closed container will explode.
- Hot piranhas explode when mixed with acetone and other organic compounds. This includes IPA, photoresist, and anything made out of nylon like spinner and developer chucks.
- If you put any acid (i.e. chrome etch) in the base piranha; it will accelerate due to the heat generated.
- Likewise, if you put any base (i.e. developer solution) in the acid piranha, it will accelerate.
- Photoresist developer is a strong base. It can cause blindness if left in the eye, and can react violently with acids. Be extremely careful in working with developer.
- Water sprayed into either piranha will accelerate the reaction. A single wet wafer doesn't introduce enough water to make a difference, but a boat with 25 wet pieces of glass could.

Instructions for safe use of Piranha:

- Substrate should be rinsed and dried before placing them in a piranha bath. Piranhas are used to remove photoresist and acetone **residue**, not the compounds themselves.
- Do not store wash bottles containing organic compounds on the piranha deck.
- No crystal bond stripping on the piranha deck.
- No Photoresist stripping near piranha deck.
- Cold acid Piranha can be used to clean glass Chromium photomasks

7. Process Gas Safety Issues

At the exception of nitrogen which is shared by all the users of the lab, other gases are administered by each group for their own needs. Nevertheless because of safety concerns, importing new gas cylinders into LAMP must be approved in advanced by the lab manager.

As explained in the section 5 of this guide (emergency procedures), hazardous gases are used in this lab and therefore every person working in LAMP should be clearly aware of the emergency procedure resulting from an accidental gas release.

MSDS sheets for each gases we use at LAMP are available (MSDS sheet binder) in the cleanroom area. If importing a new chemical into the facility, MSDS sheets need to be

obtained before purchasing the product. (Link for Online MSDS info). The MSDS for the gases currently used in LAMP can be viewed at the following link.

Users of LAMP who are directly handling these gases should also read the following Standard Operating Procedures for the use of gases in LAMP. This SOP offers a detailed description of the alarm system put in place in LAMP to detect and annunciate the presence of hazardous gases.

Standard Operating Procedure #2
Hydrofluoric acid (HF) and other HF-based solutions

Facility: Laboratory for Advanced Materials Processing
2225 JM Patterson bldg, Materials Science and Engineering
University of Maryland, College Park MD 20742
(301) 405 7250

Lab Director: Gary Rubloff
2145 AV Williams Bldg
(301) 405 2949

Lab Manager: Laurent Lecordier
2147 AV Williams Bldg
(301) 405 5858, cell (301) 602 9858

Scope: This SOP reviews the main safety issues related to the use of hydrofluoric acid.

This SOP is adapted from the content of the hydrofluoric acid SOP listed on the LAMP website at http://www.enma.umd.edu/LAMP

Last revision: 09/08/04 by Laurent Lecordier

1- General notice

(*These are not authorized official regulations for general use of HF and HF-based solutions. But, these are valuable rules to protect your safety and everyone should follow these rules whenever using HF in the LAMP cleanroom.)*

5. Before you start, read the Material Safety Data Sheet for hydrofluoric acid carefully as well as of solutions containing HF such as Buffered Oxide Etch (BOE) (http://www.enma.umd.edu/LAMP/lamp_msds.htm).
   More details about medical treatment for HF exposure available here (pdf format)
   Additional safety information is also listed in the Lab Safety section of this web site.

6. **Hydrofluoric acid is not like any other acids. It is considered as extremely hazardous either as a liquid or vapor. HF can cause severe burns which can take up to 24 hours before being visible or painful. However it will readily be absorbed into the skin and bind with calcium and magnesium to form insoluble salts. These insoluble salts will interfere with cellular metabolism, causing cellular necrosis and death.**

7. You must know that BOE is not a dilute HF. The ratio given on the BOE container is buffer to HF, so the fluorine content is the same as in HF for any ratio

8. Any LAMP users who want to use HF or HF-based solution such as BOE must be qualified and authorized by the lab manager prior to do any work.

9. During the qualification process, the lab manager will insure that the Materials Safety Data Sheets for HF-based chemicals have been carefully read and understood, and that the procedures detailed in this SOP are thoroughly followed.

10. The list of the authorized users is published on this web site. If your name is not on this list, you are not allowed to use HF or HF-based solutions at any time.

11. Any accident regarding the use of HF must be reported without delay to the lab manager.

2 - Protection equipment

1. The handling of HF solutions require special protection equipment in addition to the regular clean room protection outfit (see Lab Safety page) .

2. The additional protective equipment include: a full face shield, PVC or neoprene gloves (regular Nitrile gloves used in LAMP will not provide sufficient protection), as well as a PVC acid apron to wear on top of the lab coat.

Gloves are located in the acid cabinet, apron and mask are available in the fitting room.

3. As a reminder, open-toed shoes are not allowed when working in the lab and bare legs must be covered by wearing a full size bunny suit.

3 - HF handling

3. HF solutions, as well as any corrosive or hazardous substances, can only be used in LAMP during operational hours (9 am to 6 pm, Monday to Friday) and requires at all time the presence of a second knowledgeable user (buddy system).

4. HF vapors are extremely hazardous. Therefore HF solutions can be only handled under the flow hood dedicated to work with chemicals.

5. Whenever handling HF, all containers used during the experiment must be very clearly labeled and a warning sign, visible by any user working under the flow hood, must be posted at all time to indicate that the solutions contains HF.

6. After completion of the work, the user will insure that all surfaces in contact with HF have been carefully rinsed with DI water and blown dry. The user must also insure that the HF bottle is perfectly dry before being stored in the acid cabinet.

4 - HF waste disposal

4. You must know that BOE is not a dilute HF. The ratio given on the BOE container is buffer to HF, so the fluorine content is the same as in HF for any ratio. For this reason, the same amount of Calcium Chloride must be used when neutralizing BOE as when neutralizing HF.

5. HF solutions or BOE must be collected in the dedicated plastic containers, located on the tray next to the flow hood

6. Do not completely fill up the waste container with HF solution.

7. The waste containers will be discarded by the student in charge of the waste management according to DES waste management procedure.

5 - Emergency procedure

18. As stipulated earlier HF solutions are considered extremely hazardous because their effects are not immediate and the fluoride ion will penetrate the skin causing destruction of the deep tissue layers and even bone. It has been reported that as little as 7 ml of anhydrous HF in contact with the skin untreated can bind on the calcium in a normal size adult.

19. In case of large exposure, the victim should be removed from the contaminated area, placed under a safety shower while emergency personal is contacted (911)

    In any case, even if the burn appear initially minor, you must seek immediate medical attention. A copy of the MSDS that contains a note to the physician should be brought with you.

20. All contaminated clothing should be removed immediately with appropriate gloves and safely discarded.

21. In case of contact with the skin, the affected area must be immediately rinsed with large amounts of water for at least 15 min. However washing off the skin will not be sufficient. A calcium gluconate gel contained in a white tube is available in the LAMP facility (in the First Aid box located to the right of the lab entrance door). The gel should be massaged over the affected area. When applying the gel, the washing with water can be reduced from 15 to 5 min. The gel should be reapplied at regular intervals.

22. In case of contact with the eye, irrigate the eye for at least 30 minutes, keeping the eyelids apart and away from eyeballs during irrigation. Place ice pack on eyes until reaching emergency room.

6 - Supply and storage

1. In order to limit the number of HF containers in the lab, all solutions containing HF are supplied by the lab. If for specific research purposes, you need your dedicated source of hydrofluoric acid, you must request the authorization from the lab manager first.

2. Supplied HF solutions are typically diluted to 37%. If you need to adjust this concentration, you will supply your own container for storage, a polyethylene bottle with a positive closure (never store in a glass container since HF attacks glass and other silicon containing compounds)
3. All HF-containing solutions will be stored in the acid cabinet located under the flow hood. It is not allowed to leave the lab with a HF solution left on the bench top under the flow hood.
4. If you notice that the supply of HF or BOE is running out, contact the student in charge of chemicals inventory (do not wait the last minute though since it can take up to 4 weeks to renew the supply)

Standard Operating Procedure #3
Piranha solution

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Scope: This SOP reviews the main safety issues related to the use of Piranha solution.

This SOP is adapted from the content of the Piranha solution SOP listed in the LAMP website at http://www.enma.umd.edu/LAMP

Last revision: 09/08/04 by Laurent Lecordier

1 - General notice

1. A piranha is used to remove organic residues from substrates. Two different solutions are used. The most common is the acid piranha: a 3:1 mixture of concentrated sulfuric acid (H2SO4) with hydrogen peroxide (H2O2). Also used is the base piranha: a 3:1 mixture of ammonium hydroxide (NH4OH) with hydrogen peroxide (H2O2). Both are equally dangerous when hot, although the reaction in the acid piranha is self-starting whereas the base piranha must be heated to 60 degrees before the reaction takes off. [1]

   There are many things which will cause the reaction to accelerate out of control. "Out of control" can mean anything from the piranha foaming out of its bin and on the deck, to an explosion with a huge shock wave including glove and acid-gown shredding glass sharps. Piranhas burn organic compounds. If you provide sufficient fuel for them (i.e. photoresist, IPA), they will generate enormous quantities of heat and gas. [1]

2. Any LAMP users who want to use Piranha solutions in LAMP solution must be qualified and authorized by the lab manager prior to do any work.

3. The list of the authorized users is published on this web site. If your name is not on this list, you are not allowed to use Piranha solutions at any time.

4. Any accident regarding the use of Piranha solutions must be reported without delay to the lab manager.

2 - Protection equipment

1. The handling of Piranha solutions requires special protection equipment in addition to the regular clean room protection outfit (see Lab Safety page) .

2. The additional protective equipment include: a full face shield, heavy duty rubber gloves (regular Nitrile gloves used in LAMP will not provide sufficient protection), as well as an acid apron to wear on top of the lab coat.
   Gloves are located in the acid cabinet, apron and mask are available next to the wet bench.

3. As a reminder, open-toed shoes are not allowed when working in the lab and bare legs must be covered by wearing a full size bunny suit.

3 - Piranha solution handling

1. Piranha solutions, as well as any corrosive or hazardous substances, can only be used in LAMP during operational hours (9 am to 6 pm, Monday to Friday) and requires at all time the presence of a second knowledgeable user (buddy system).

2. Whenever handling Piranha, only use glass containers (preferably Pyrex). Containers used during the experiment must be very clearly labeled and a warning sign, visible by any user working under the flow hood, must be posted at all time to indicate that the solutions contains Piranha mixture.

3. Mix the solution in the flow hood with the sash between you and the solution. Wear the full protection.

4. When preparing the piranha solution, always add the peroxide to the acid. The H2O2 is added immediately before the etching process because it immediately produces an exothermic reaction with gas (pressure) release. If the H2O2 concentration is at 50% or greater, an explosion could occur.

5. Piranha solution is very energetic and potentially explosive. It is very likely to become hot, more than 100 degrees C. Handle with care.

6. Substrate should be rinsed and dried before placing them in a piranha bath. Piranhas are used to remove photoresist and acetone **residue**, not the compounds themselves

7. Leave the hot piranha solution in an open container until cool.

8. Never store hot piranha solutions. Piranha stored in a closed container will likely explode.

9. Adding any acids or bases to piranha or spraying it with water will accelerate the reaction. This includes Photoresist, which is a strong base.

10. Mixing hot piranha with organic compounds may cause an explosion. This includes acetone, photoresist, isopropyl alcohol, and nylon.

11. Do not store wash bottles containing organic compounds on the piranha deck.

4 - Piranha waste disposal

1. The primary hazard from storage of piranha etch waste is the potential for gas generation and over pressurization of the container when the solution is still hot. If you store a hot solution in a air tight container, it will explode!

2. Therefore prior to store the piranha solution, it must be left in an open container in order to cool down for several hours (overnight). It is your responsibility to make sure that the open container is very clearly labeled and left in a safe area for overnight cool down.

3. Once cooled down, the solution can be transferred into a closed glass container for waste storage. The container must be very clearly labeled with the solution name and composition and must include VERY VISIBLE warning signs not to add any other types of chemicals.

5 - Emergency procedure

1. In case of large exposure, the victim should be removed from the contaminated area, placed under a safety shower while emergency personal is contacted (911)

2. All contaminated clothing should be removed immediately with appropriate gloves and safely discarded.

3. In case of contact with the skin, the affected area must be immediately rinsed with large amounts of water for at least 15 min.

4. In case of contact with the eye, irrigate the eye for at least 30 minutes, keeping the eyelids apart and away from eyeballs during irrigation. Place ice pack on eyes until reaching emergency room.

5. In case of inhalation, it may irritate the respiratory tract. Conscious persons should be assisted to an area with fresh, uncontaminated air. Seek medical attention in the event of respiratory irritation, cough, or tightness in the chest. Symptoms may be delayed.

6 - Supply and storage

1. Do not store piranha. Mix fresh solution for each use. Excess solutions should be disposed as explained in paragraph #4.

Appendix IV

Chemical Inventory

and

Material Safety Data

(to be supplied by Laboratory Supervisor)

Notice: Materials Safety Data Sheets are listed on the LAMP website at
http://www.enma.umd.edu/LAMP/lamp_msds.htm

Wet chemical inventory

Chemical	Supplier	Volume	MSDS
Acetone, 99.9+%	Sigma Aldrich	2L	Electronic Copy
Ammonium cerium nitrate	Aldrich	50g	Electronic Copy
Ammonium hydroxide	Fisher Scientific	2.5L	Electronic Copy
AZ 400K Developer	Clariant	1Ga	Electronic Copy
Bismuth acetate	Alfa Aesar	50g	Electronic Copy
Butanol (1-)	Aldrich		Electronic Copy
Ethyl alcohol, reagent	Aldrich	1L	Electronic Copy
Gold	Alfa Aesar	1g	Electronic Copy
Gold etch - iodine		500ml	Electronic Copy
Hafnium tetrakis dimethylamide	Aldrich	20 g	Electronic Copy
Hafnium tetrakis ethylmethylamide	Epichem	50 g	Electronic Copy
Hydrochloric acid 50%	Fisher chemical	500ml	Electronic Copy
Hydrofluoric acid (37%)		1l	Electronic Copy
Hydrofluoric acid 10%		1l	Electronic Copy
Hydrofluoric acid 5%		1l	Electonic & hard copy
Hydrofluoric acid, ammonium fluoride 6:1 (Buffered Oxide Etch)	JT Baker	9lb	Electronic Copy
Hydrogen peroxide H2O2 30%	Fisher Scientific	500ml	Electronic Copy
Lead Titanium Isopropoxide	Alfa Aesar	100ml	Electronic Copy
Lead Zirconium ethylhexano isopropoxide, 10%W/V	Alfa Aesar	100ml	Electronic Copy

Methanol	J.T.Baker	4L	Electronic Copy
Methoxy ethanol (2-), 99%	Alfa Aesar	1L	Electronic Copy
Methylsilsquioxane 35% in mix solvents		100ml	Electronic Copy
Nitric acid 70%	JT Baker	2.5l	Electronic Copy
O-phosphoric Acid	Fisher	500ml	Electronic Copy
Propanol (1-)	Fisher Scientific	500ml	Electronic Copy
Propanol (2-)	Aldrich	4L	Electronic Copy
Sodium hydroxide	JT Baker	500g	Electronic Copy
Sodium silicate (14% NaOH, 27%SiO2)	Sigma Aldrich	1L	Electronic Copy
Sulfuric acid	Fisher Scientific	2.5L	Electronic Copy
Tetrachloro ethylene TCE 1,1,1	Alfa Aesar	4L	Electronic Copy
Tetramethyl ammonium hydroxide	Aldrich	1l	Electronic Copy
Titanium 2-ethyl hexoxide	Alfa Aesar	500g	Electronic Copy
Tetrakis(dimethylethylamido)titanium	Aldrich	25 g	Electronic Copy
Titanium isopropoxide	InorgTech	100g	Electronic Copy
Toluene	Fisher Scientific	4L	Electronic Copy
Trichloroethylene	Fisher	2L	Electronic Copy
Xylene	Fisher Scientific	1l	Electronic Copy
Zinc 2-Ethylhexanoate	Alfa Aesar	100gm	Electronic Copy
Zinc neodecanoate	Alfa Aesar	250g	Electronic Copy
Zirconium 2-ethylhexanoate	Alfa Aesar	100gm	Electronic Copy

Gas inventory

Ammonia (NH3)	Air Products	50 lbs	Electronic Copy
Sulfur hexafluoride	Air Products	7 lbs	Electronic Copy
Hydrogen	Air Products	196 ft3	Electronic Copy
Hydrogen	Praxair	196 ft3	Electronic Copy
Nitrogen	Praxair		Electronic Copy
Argon	Praxair		Electronic Copy
Helium	Praxair		Electronic Copy