Standard Operating Procedure (SOP) for Chemical Vapor Deposition (CVD) Operation (Major/High Hazard Operations)

PI Name: Yat Li **Date:** 01/08/2013

Name of Lab orUnit: 198 PSB

Review any applicable manufacturer/vendor safety information before developing standard operating procedure and append UC Approved Chemical SOP, if available, or SDS and other Chemical reference materials if UC Chemical SOP is not avaialble.

#1	Scope of Work/Activity: Two customized CVD systems are used for the synthesis of nanomaterials. The reaction chambers of these CVDs are quartz tubes, which are used to accommodate growth substrate and solid precursors. The chamber can be heated by a split-hinged three heating zone round tubular furnace. Each heating zone is capable of operation at temperatures up to 1200^{o}C, and the heating rate and temperature profile can be programmed by a digital temperature controller. The system can be operated in the pressure range of 20 mtorr to atmospheric pressure. Hazardous materials that will be used (see appended Chemical SOPs): Dilute silane (100ppm in H_2), Hydrogen, Ammonia
#2	Specific Safety and Environmental Hazards: State the specific hazard and consequences if procedure not followed to person, environment, or property. Release of process gases into hood enclosure and/or lab can result in fire and chemical exposure. User contact with hot surfaces can result in burns.

#3	<u>Describe in detail how the hazards will be controlled.</u> Hazard 1: There is a chance of gas leakage into fume hood if the user fails to get a good sealing of the loading chamber. The process gases that may be involved in the reaction include ammonia, diluted silane (100ppm in H_2), and hydrogen. User: • Make sure the CVD system is leak tight during the pump-fill cycles before switching to process gas. ○ Leak test system by ensuring it holds a vacuum. • The fume hood door should be closed all the time except loading sample/quartz tube. Hazard 2: High temperature reaction (up to 1100 ^oC). User: • DO NOT change the position of thermocouples. • Double check the temperature setting before the experiment, and monitor the temperature during the reaction. • DO NOT take out the susceptor before it is cooled down (below 50^oC). • No flammable solvent in the hood. Hazard 3: Vacuum system User: • DO NOT pressurize the system. The reaction pressure should not exceed atmospheric pressure • Double check the pressure controller setting before the experiment • Monitor the gas flow rate and pressure of the reactor during the reaction Hazard 5: Chemicals User: • Ammonia is corrosive and flammable. It is a colorless highly irritating gas with a sharp suffocating odor. The ammonia is stored in a ventilated gas cabinet and always used in a closed, purged system. • Silane (100 ppm in hydrogen). Silane is a pyrophoric gas at concentrations > 4.5%. At 100 ppm, the silane concentration is below its lower flammability limit, however, hydrogen is a flammable gas. The silane/hydrogen mixture is stored in a ventilated gas cabinet and always used in a closed, purged system. **Engineering Controls**. The CVD systems are installed in a walk-in fumehood. The fumehood door is closed during the experiment except loading sample and transferring susceptor. **Emergency shutdown** procedures. • Press the red "Emergency Stop" button near the door to switch off all gas supply. • Switch off the power supply for CVD systems.
#4	<u>Designated Area:</u> Indicate the designated area for performing this process in the laboratory. CVD systems are installed in a walk-in fumehood. The fumehood door is closed during the experiment except loading sample and transferring susceptor.
#5	<u>Personal Protective Equipment (PPE):</u> User should wear gloves, safety glasses, and flame resistant lab coat (See "Chemical Hazards and Controls" Sections).
#6	<u>Important Steps to Follow:</u> List the specific sequence staff should follow to avoid hazard. 1. Load substrate/reactant into a quartz tube. 2. Load the quartz tube into CVD system. Seal the interface of the quartz tube and metal connector by tightening the metal nuts at the two ends of the quartz tube. 3. Pump-fill the system to evacuate the air in the system and to check if there is a gas leakage. 4. Close the furnace. 5. Set temperature (^oC), gas flow rate (sccm) and pressure (torr) of CVD system. 6. Perform reaction. Monitor the temperature and, gas flow rate and pressure during the reaction. 7. Cool down the system by setting the temperature to 0 ^oC. Evacuate the system (optional). 8. Open the furnace when the temperature drops below 100 ^oC. 9. Backfilled the system to atmospheric pressure (760 torr) with Ar or N_2. 10. Unload the quartz tube and take the sample out.

#7 Emergency First Aid Procedures:

If inhaled

If breathed in, move person into fresh air. If not breathing, give artificial respiration. Consult a physician.

In case of skin contact

Take off contaminated clothing and shoes immediately. Wash off with soap and plenty of water. Consult a physician (bring Material Safety Data Sheet with you).

In case of eye contact

Rinse thoroughly with plenty of water for at least 15 minutes and consult a physician. Continue rinsing eyes during transport to hospital.

If swallowed

Do NOT induce vomiting. Never give anything by mouth to an unconscious person. Rinse mouth with water. Consult a physician.

#8 Training & Competency Requirements:

Prior to entering and working in the laboratory, you must have completed the EH&S class "Introduction to Laboratory Safety" and the Lab-Specific Training Checklist.

Review SOP with LSR and PI

New user can get trained by any experienced user, but should be qualified by Yat Li or Yichuan Ling.

#9 Identify waste stream and disposition of unused stock of chemicals

Waste is normally not generated during this process. When metal sources (Zn, W, Fe, Ga, In) become too small for reuse, they are disposed of with hazardous waste.

#10 Decontamination and spill clean-up procedures.

Do not attempt to clean up any spill or release for which you are not fully trained and equipped. Contact 911 and ask for EH&S assistance for spill cleanup.

In the event of a spill or gas release:

a. Alert people in the laboratory to evacuate.

b. Press the red "Emergency Stop" button by the door to shut down the MOCVD and stop gas flow.

c. Close doors to affected area.

d. Call for Emergency Response: 911

e. Post with danger signs and have person knowledgeable of incident and laboratory assist emergency personnel

#11 Laboratory Emergency Response Equipment: All research personnel must know location of nearest fire alarm pull station and emergency shower/eyewash.

a. Note location and use of any emergency response equipment specific to process (e.g., Calgonate gel, Class D fire extinguisher)

Item	Location
Eyewash/Safety Shower	Near the door
Chemical Spill Kit	N/A
Fire Extinguisher	Outside the door
Telephone	Student office

As the Principal Investigator, it is your responsibility to ensure that all individuals listed in this protocol are taught the correct procedures for the safe handling of hazardous materials involved in this study. It is also your responsibility to assure that your personnel complete Laboratory Safety Training and other applicable safety training courses.

I have read, asked questions, and understand the hazards of and safe working procedures for the activity/materials described herein.

x I understand that checking this box constitutes my approval of this document on 6/16/2015

PI Signature/Approval: Yat Li DATE

Chemical Hazards and Controls

Ammonia

This is a Chemical Hazard and Control template and is not complete until: 1) Chemical specific information is entered into the boxes below 2) Itis appended to the protocol/procedural SOP and 3) Complete SOP has been signed and dated by the PI and relevant lab personnel.

Department:	Chemistry
Date SOP was written:	01/08/13
Date SOP was approved by PI/lab supervisor:	
Principal Investigator:	Yat Li
Internal Lab Safety Coordinator/Lab Manager:	Tianyu Liu
Lab Phone:	
Office Phone:	(831) 459-1952
Emergency Contact:	Yat Li *(Name and Phone Number)*
Location(s) covered by this SOP:	PSB 198 *(Building/Room Number)*

Physical & Chemical Properties/Definition of Chemical Group

CAS#: 7664-41-7

Class:

Molecular Formula: H_3N

Form (physical state): compressed gas, strong odor

Color: colorless

Boiling point: -33^{o}C at 1 atm pressure.

Melting point: -78^{o}C

Density = 0.590 g/mL

Potential Hazards/Toxicity

Ammonia is both caustic and hazardous. Ammonia is a colorless highly irritating gas with a sharp suffocating odor. It dissolves easily in water to form ammonium hydroxide solution which can cause irritation and burns. Because NH_3 boils at −33.34 °C (−28.012 °F) at a pressure of 1 atmosphere, the liquid must be stored under high pressure or at low temperature. It is usually shipped as a compressed liquid in steel cylinders. Ammonia is not highly flammable at very low or very high concentrations; CAUTION avoid a moderate gas release in a closed environment (room) with an ignition source (light switch) and oxygen present [Lower explosion limit 15 %(V) with Upper explosion limit 25 %(V)]. Containers of ammonia may explode when exposed to high heat.

Caution working with ammonia and chlorine: @ high temperature and in the presence of a suitable catalyst, ammonia is decomposed into its constituent elements. Ignition occurs when chlorine is passed into ammonia, forming nitrogen and hydrogen chloride; if chlorine is present in excess, then the highly explosive nitrogen trichloride (NCl_3) is also formed.

Most people are exposed to ammonia from breathing its gas or vapors. Ammonia gas is lighter than air and will rise, so that generally it does not settle in low-lying areas. However, in the presence of moisture, ammonia can form vapors that are heavier than air. These vapors can spread along the ground or other low-lying areas.
Inhalation LC_{50} - rat - 4 h - 2000 ppm

Personal Protective Equipment (PPE)

Respiratory Protection

Respirators should be used only under any of the following circumstances:

- As a last line of defense (i.e., after engineering and administrative controls have been exhausted).
- When Permissible Exposure Limit (PEL) has exceeded or when there is a possibility that PEL will be exceeded.
- Regulations require the use of a respirator.
- An employer requires the use of a respirator.
- There is potential for harmful exposure due to an atmospheric contaminant (in the absence of PEL)
- As PPE in the event of a chemical spill clean-up process

Lab personnel intending to use/wear a respirator mask must be trained and fit-tested by EH&S. This is a regulatory requirement (http://ehs.ucsc.edu/programs/safety-ih/respiratory-protection.html).

Hand Protection

Wear Flame resistant gloves when changing ammonia gas cylinders.

NOTE: Consult with your preferred glove manufacturer to ensure that the gloves you plan on using are compatible with ammonia.

Refer to glove selection chart from the links below:

http://www.ansellpro.com/download/Ansell_8thEditionChemicalResistanceGuide.pdf

OR

http://www.allsafetyproducts.biz/page/74172

OR

http://www.showabestglove.com/site/default.aspx

OR

http://www.mapaglove.com/

Eye Protection

ANSI approved, tight-fitting safety glasses/goggles. Face shields are also recommended.

Skin and Body Protection

Flame-resistant lab coats must be worn and be appropriately sized for the individual and buttoned to their full length. Laboratory coat sleeves must be of sufficient length to prevent skin exposure while wearing gloves. Full length pants and closed-toe shoes must be worn at all times by all individuals that are occupying the laboratory area. The area of skin between the shoe and ankle should not be exposed.

Hygiene Measures

Avoid contact with skin, eyes and clothing. Wash thoroughly and immediately after handling. Remove contaminated clothing.

Engineering Controls

Cylinder is stored/used in a certified ventilated gas cabinet and directly plumbed to the MOCVD located in a walk-in fume hood. System is equipped with emergency stop switch to shut down gas flow.

First Aid Procedures

If inhaled

If breathed in, move person into fresh air. If not breathing, give artificial respiration. Consult a physician.

In case of skin contact

Take off contaminated clothing and shoes immediately. Wash off with soap and plenty of water. Take victim immediately to hospital. Consult a physician (bring Material Safety Data Sheet with you).

In case of eye contact

Rinse thoroughly with plenty of water for at least 15 minutes and consult a physician. Continue rinsing eyes during transport to hospital.

If swallowed
Do NOT induce vomiting. Never give anything by mouth to an unconscious person. Rinse mouth with water. Consult a physician.

Special Handling and Storage Requirements

Precautions for safe handling

Handle this material only in sealed, purged systems. Handle sealed gas cylinders in accordance with CGA P-1, *Safe Handling of Compressed Gases in Containers.*

Keep away from sources of ignition. Take measures to prevent the buildup of electrostatic charge.

Conditions for safe storage
Keep cylinder in ventilated gas cabinet.

Contents under pressure.

Incompatible with the Following Materials

Materials to avoid
Oxidizing agents, Iron, Zinc, Copper, Silver/silver oxides, Cadmium/cadmium oxides, Alcohols, acids, Halogens, Aldehydes

Spill and Accident Procedure

Release– Dial **911** and ask for EH&S assistance.

Alert people in the laboratory to evacuate.

Press the red "Emergency Stop" button by the door to shut down the MOCVD and stop gas flow.

Close doors to affected area.

Post with danger signs and have person knowledgeable of incident and laboratory assist emergency responders

Chemical Spill Dial 911

Spill – Dial **911** and ask for EH&S assistance or call EH&S directly x459-2553.

Chemical Spill on Body or Clothes – Remove clothing and rinse body thoroughly in emergency shower for at least 15 minutes. Seek medical attention if needed. *Notify supervisor and EH&S via 911 immediately.*

Chemical Splash Into Eyes – Immediately rinse eyeball and inner surface of eyelid with water from the emergency eyewash station for 15 minutes by forcibly holding the eye open. Seek medical attention. *Notify supervisor and EH&S via 911 immediately.*

Mucous Membrane Exposure: Flush the affected area for 15 minutes using an eyewash station.

Needlestick/Puncture Injuries – Wash the affected area with soap and warm water for 15 minutes. For employees, follow the instructions at the Risk Services website: http://risk.ucsc.edu/workerscomp/injuryreportinghowto.html

Medical Emergency Dial 911

Life Threatening Emergency, After Hours, Weekends And Holidays – Dial **911**

Non-Life Threatening Emergency – For employees, follow the instructions at the Risk Services website: http://risk.ucsc.edu/workerscomp/injuryreportinghowto.html

Note: All serious injuries must be reported to EH&S as soon as possible.

Decontamination/Waste Disposal Procedure

Cylinders that contained ammonia must be returned to the supplier.

Waste Procedures

General hazardous waste management guidelines: http://ehs.ucsc.edu/programs/waste-management/index.html

- Contact EH&S at x9-3086 for questions

Safety Data Sheet (SDS) Location

Online SDSs can be accessed at: http://www.ucmsds.com/?X .

NOTE

Any deviation from this Procedural/Chemical Handling SOP requires approval from PI.

Silane (100 ppm in Hydrogen)

This is a Chemical Hazard and Control template and is not complete until: 1) Chemical specific information is entered into the boxes below 2) Itis appended to the protocol/procedural SOP and 3) Complete SOP has been signed and dated by the PI and relevant lab personnel.

Purpose

Silane is purchased as a 100 ppm mixture in hydrogen for use in the MOCVD system in the lab. The information below, for pure silane gas, is provided for reference. See the Ammonia SOP above for Engineering Controls, First Aid, and Chemical Release and Accident Procedures.

Physical & Chemical Properties/Definition of Chemical Group

CAS#: 7803-62-5

Class: Pyrophoric and highly flammable gas

Molecular Formula: SiH4

Molecular Weight: 32.12 g/mol

Form (physical state): gas

Color: colorless

Melting Point:-185 ℃

Boiling point:-112.15 ℃

Lower Flammability Limit (in air) = 1.4%

Upper Flammability Limit (in air) = 96.0%

May undergo bulk autoignition at > 4.5%

Potential Hazards/Toxicity

- Pyrophoric, flammable, high-pressure gas.
- Can ignite on contact with air.
- May form explosive mixtures with air.
- Does not need a source of ignition.
- Respiratory irritant.
- May cause respiratory system damage.
- Self-contained breathing apparatus and protective clothing may be required by rescue workers.
- Under ambient conditions, this colorless gas has a choking odor.

Cal-OSHA PEL = 5 ppm.

Chemical Hazards and Controls

Hydrogen

This is a Chemical Hazard and Control template and is not complete until: 1) Chemical specific information is entered into the boxes below 2) Itis appended to the protocol/procedural SOP and 3) Complete SOP has been signed and dated by the PI and relevant lab personnel.

Purpose

Hydrogen (H2) is a highly flammable gas. Hydrogen gas forms explosive mixtures with air if it is 4–74% concentrated and forms explosive mixtures with chlorine if it is 5–95% concentrated. The mixtures spontaneously explode by spark, heat or sunlight. Auto-ignition temperature of Hydrogen: The temperature of spontaneous ignition in air, is 500 ℃ (932 ℉). The detection of a burning hydrogen leak may require a flame detector; such leaks can be very dangerous. Hydrogen reacts with every oxidizing element.

Hydrogen poses a number of hazards to human safety, from potential detonations and fires when mixed with air to being an asphyxiant in its pure, oxygen-free form. Hydrogen dissolves in many metals. In addition to leaking out, may have adverse effects on metals, such as hydrogen embrittlement, leading to cracks and explosions. Hydrogen gas leaking into external air may spontaneously ignite. Moreover, hydrogen fire, while being extremely hot, is almost invisible, and thus can lead to accidental burns.

Even interpreting the hydrogen data (including safety data) is confounded by a number of phenomena. Hydrogen detonation parameters such as critical detonation pressure and temperature, strongly depend on the container geometry.

If not handled and stored properly, Hydrogen gas can pose a serious threat to the health and safety of laboratory personnel & emergency responders and also to the property. This SOP helps to understand how to properly store & handle hydrogen.

Physical & Chemical Properties/Definition of Chemical Group

CAS#: 1333-74-0

Class: Highly flammable gas

Molecular Formula: H_2

Form (physical state): compressed gas

Color: colorless

Boiling point: -252.87 ℃

Melting point: -259.14 ℃

Density = 0.08988 g/L

Potential Hazards/Toxicity

Hydrogen (H2) is a highly flammable gas. Hydrogen gas (dihydrogen or molecular hydrogen) is highly flammable and will burn in air at a very wide range of concentrations between 4% and 75% by volume.

Personal Protective Equipment (PPE)

Respiratory Protection

Respirators should be used only under any of the following circumstances:

- As a last line of defense (i.e., after engineering and administrative controls have been exhausted).

- When Permissible Exposure Limit (PEL) has exceeded or when there is a possibility that PEL will be exceeded.
- Regulations require the use of a respirator.
- An employer requires the use of a respirator.
- There is potential for harmful exposure due to an atmospheric contaminant (in the absence of PEL)
- As PPE in the event of a chemical spill clean-up process

Lab personnel intending to use/wear a respirator mask must be trained and fit-tested by EH&S. This is a regulatory requirement (http://ehs.ucsc.edu/programs/safety-ih/respiratory-protection.html).

Hand Protection

Wear Flame resistant gloves when changing hydrogen gas cylinders.

NOTE: Consult with your preferred glove manufacturer to ensure that the gloves you plan on using are compatible with hydrogen.

Refer to glove selection chart from the links below:

http://www.ansellpro.com/download/Ansell_8thEditionChemicalResistanceGuide.pdf

OR

http://www.allsafetyproducts.biz/page/74172

OR

http://www.showabestglove.com/site/default.aspx

OR

http://www.mapaglove.com/

Eye Protection

ANSI approved, tight-fitting safety glasses/goggles. Face shields are also recommended.

Skin and Body Protection

Flame-resistant lab coats must be worn and be appropriately sized for the individual and buttoned to their full length. Laboratory coat sleeves must be of sufficient length to prevent skin exposure while wearing gloves. Full length pants and closed-toe shoes must be worn at all times by all individuals that are occupying the laboratory area. The area of skin between the shoe and ankle should not be exposed.

Hygiene Measures

Avoid contact with skin, eyes and clothing. Wash thoroughly and immediately after handling. Remove contaminated clothing.

Engineering Controls

Cylinder is stored/used in a certified ventilated gas cabinet and directly plumbed to the MOCVD located in a walk-in fume hood. System is equipped with emergency stop switch to shut down gas flow.

First Aid Procedures

If inhaled

If breathed in, move person into fresh air. If not breathing, give artificial respiration. Consult a physician.

In case of skin contact

Take off contaminated clothing and shoes immediately. Wash off with soap and plenty of water. Take victim immediately to hospital. Consult a physician (bring Material Safety Data Sheet with you).

In case of eye contact

Rinse thoroughly with plenty of water for at least 15 minutes and consult a physician. Continue rinsing eyes during transport to hospital.

If swallowed
Do NOT induce vomiting. Never give anything by mouth to an unconscious person. Rinse mouth with water. Consult a physician.

Special Handling and Storage Requirements

Precautions for safe handling

Handle this material only in sealed, purged systems. Handle sealed gas cylinders in accordance with CGA P-1, *Safe Handling of Compressed Gases in Containers.*

Keep away from sources of ignition. Take measures to prevent the buildup of electrostatic charge.

Conditions for safe storage
Keep cylinder in ventilated gas cabinet.

Contents under pressure.

Cal/OSHA regulation T8 1740(g) requires that, oxygen cylinders in storage be separated from hydrogen or other fuel-gas cylinders or combustible materials (especially oil or grease) by a minimum distance of 20 feet or by a non-combustible barrier at least five feet high and with a fire resistance rating of least one-half hour. Section 4650 requires the barrier to be at least 18 inches above the tallest cylinder.

**In simple words, DO NOT store Hydrogen & Oxygen/other oxidizing gases, oxidizing materials together.*

Incompatible with the Following Materials

Materials to avoid

Spill and Accident Procedure

Release– Dial **911** and ask for EH&S assistance.

Alert people in the laboratory to evacuate.

Press the red "Emergency Stop" button by the door to shut down the MOCVD and stop gas flow.

Close doors to affected area.

Post with danger signs and have person knowledgeable of incident and laboratory assist emergency responders

Chemical Spill Dial 911

Spill – Dial **911** and ask for EH&S assistance or call EH&S directly x459-2553.

Chemical Spill on Body or Clothes – Remove clothing and rinse body thoroughly in emergency shower for at least 15 minutes. Seek medical attention if needed. *Notify supervisor and EH&S via 911 immediately.*

Chemical Splash Into Eyes – Immediately rinse eyeball and inner surface of eyelid with water from the emergency eyewash station for 15 minutes by forcibly holding the eye open. Seek medical attention. *Notify supervisor and EH&S via 911 immediately.*

Mucous Membrane Exposure: Flush the affected area for 15 minutes using an eyewash station.

Needlestick/Puncture Injuries – Wash the affected area with soap and warm water for 15 minutes. For employees, follow the instructions at the Risk Services website: http://risk.ucsc.edu/workerscomp/injuryreportinghowto.html

Medical Emergency Dial 911

Life Threatening Emergency, After Hours, Weekends And Holidays – Dial **911**

Non-Life Threatening Emergency – For employees, follow the instructions at the Risk Services website: http://risk.ucsc.edu/workerscomp/injuryreportinghowto.html

Note: All serious injuries must be reported to EH&S as soon as possible.

Decontamination/Waste Disposal Procedure

Cylinders that contained hydrogen must be returned to the supplier.

Waste Procedures

General hazardous waste management guidelines: http://ehs.ucsc.edu/programs/waste-management/index.html

- Contact EH&S at x9-3086 for questions

Safety Data Sheet (SDS) Location

Online SDSs can be accessed at: http://www.ucmsds.com/?X .

NOTE

Any deviation from this Procedural/Chemical Handling SOP requires approval from PI.

Additional Hydrogen Safety Information

Safety can be achieved while handling hydrogen gas by adhering to the below mentioned protocols, *but not limited to the following*;

- Policy requires that compressed gas cylinders be double chained to a stable structure such as a wall. The first chain must be one third from the bottom of the cylinder and the second chain should be one third from the top of the cylinder. Do not use Nylon straps to secure compressed gas cylinders. Do not use table/bench clamps for securing the cylinders. Replace the straps with chains. Contact facilities and submit an FSR. Policy requires that double chains be used to secure a maximum of three cylinders clustered together. Secure cylinders of equal sizes together to avoid chaining problems.
- If compressed gas cylinder holding metal rack is used to restrain the cylinders, the rack must be bolted to the floor and the chains or rods must be at 1/3rd from the bottom and 1/3rd from the top of the cylinders. Clam shell (a cylindrical metal casing bolted to the floor) can be used to secure cylinders that need to be stored and used next to the experimental set-up.
- Always use Stainless Steel (SS) tubing to convey hydrogen gas. Teflon tubing is okay *if* specified by the manufacturer.
- Remove the regulator and place the safety cap on, when the cylinder is not in constant use.
- Hydrogen gas leak detector installation is recommended.
- Prevent hydrogen leaks by meticulously connecting gas regulator and tubing.
- Keep constant vigilance to immediately detect accidental leaks.
- Prevent accumulations of leaked hydrogen using plentiful ventilation.
- Eliminate likely ignition sources, and suspect unknown ignition sources.
- Store hydrogen gas cylinders away from electrical panels and emergency eyewash & safety shower.
- Always assume hydrogen is present, and verify the system has been purged to less than 1 percent when performing system maintenance on a hydrogen system. Inert gases such as Nitrogen & Argon can be used for purging.
- Always assume oxygen is present, and verify the system has been purged to the appropriate level when reintroducing hydrogen into a system.
- Have lab buddy system when working with highly flammable gases such as Hydrogen, Ethane, Methane, Acetylene etc.
- All users must have had hands-on training to work with highly flammable gases. The training must be documented.
- Lab personnel handling highly flammable gases must have easy access to an Emergency Eyewash & Safety Shower within 10 seconds (i.e., travel distance no greater than 100 feet).

Repair operations

- The system shall be verified safe according to proper procedures before any type of maintenance is attempted
- Includes all repairs, alterations, cleaning, or other operations performed in confined spaces in which hydrogen vapors or gases are likely to exist.
- The personnel engaged in the operations shall be advised of the hazards that may be encountered, and an attendant (lab buddy) shall be immediately available for emergency rescue if necessary

Types of Emergencies

- The principal danger from a leak is the potential burns and fires
- When a leak occurs, the area shall be completely roped off and caution signs shall be posted
- Leaks can occur near the valve/regulator/tubing/tubing bends or joints or a pumping system.
- Catastrophic fires can occur
- High-pressure gas leaks can occur

Controllable leaks

- Controllable leaks are relatively small leaks that would not result in significant release before shut-off and relief valves can be made operational.

Uncontrollable leaks

- Uncontrollable leaks may be large and involve major release.
- Large fire and explosions may occur.

Procedures to be followed during uncontrollable leaks

- The supply source shall be shut-off immediately *if possible*
- The area shall be evacuated to 152 m (500ft) from the release point
- Call 911 from campus phone or from cell phone immediately. Then immediately notify EH&S & fire department.
- Adjacent equipment shall be cooled down in case of fire.

Handling Gas Leaks from Cylinders

- Only an acceptable, approved solution shall be used when testing for leaks.
- If a cylinder safety device leaks, personnel shall not attempt to correct the leak by tightening the safety device cap while the cylinder is under pressure. The contents of the cylinder shall be emptied in a safe location. The cap shall be removed to examine the condition of the threads, correct the damage, pressurize and leak test.
- Leaking commercial cylinders should be safely vented, tagged as defective, and returned to the supplier ASAP.

Documentation of Training (signature of all users is required)

- Prior to conducting any work, designated personnel must provide training to his/her laboratory personnel specific to the hazards involved in working with these substances, work area decontamination, and emergency procedures.

- The Principal Investigator must provide his/her laboratory personnel with a copy of this SOP and a copy of the SDS provided by the manufacturer.

- The Principal Investigator must ensure that his/her laboratory personnel have attended appropriate laboratory safety training or refresher training within the last one year.

I have read and understand the content of this SOP:

Name	Signature	Date

(*Add further signature lines as necessary*)

Revision History

Version	Date	Revision Author	Summary of Changes
1	12/14/2012	Yat Li	Initial SOP author
2	01/04/2013	Nick Filipp	Revisions to process section. Added chemical information.
3	01/08/2013	Lisa Wisser	EH&S Review