NEW JERSEY INSTITUTE OF TECHNOLOGY

MICROELECTRONICS FABRICATION CENTER

CLEANROOM SAFETY MANUAL

2015

Table of Contents

1.0 INTRODUCTION

1.1 General Cleanroom Laboratory Rules

1. Authorized personnel must enter cleanroom wearing the proper attire: Robing and unrobing is from the head down (see the following sequence)

    - Bonnet over hair
    - Hood and face mask
    - Safety glasses (contact lens wearers must wear goggles in chemical areas)
    - One piece jumpsuit
    - Booties over street shoes
    - Plastic gloves

2. Log in and Log out (use card provided)

3. Absolutely no smoking, eating or drinking is allowed in the cleanroom

4. Know and follow regulations listed in Lab Protocol (see Section 1.2)

5. There must be a minimum of *2* people in the cleanroom or within easy hearing and sight range of each other at *all* times

6. Never *touch* or operate equipment unless you have been approved to do so

7. Work area is to be neat and clutter free at all times

8. Always report injuries promptly and properly

9. Never hesitate to admit you have made a mistake. This can prevent equipment damage or personnel injuries from occurring. DO NOT attempt to repair equipment, notify lab personnel.

10. Contact Campus Public Safety (ext 3111) or lab personnel in case of:

    - Any fire
    - Any exposure to hazardous chemical or gases
    - Any release of hazardous material
    - Injuries that require immediate medical attention
    - All spills
    - Laboratory evacuation

Any Violation of laboratory rules will result in loss of privileges.

1.2 NJIT Microelectronic Lab Protocol

1. The facility is available for research usage on a non-priority basis by qualified users during designated times. Qualifications will be determined by the NJIT laboratory Manager or someone designated by the manager.

2. Special Priority may be granted in rare instances by the NJIT laboratory Manager.

3. Scheduled classes have priority over all other uses.

4. Each tool requiring qualifications will have an approved user list attached at the tool station. No others may use these tools.
5. Users must log in and log out each time the classroom is used.

6. Tool users must log in and log out each time a tool is used in order to establish project charges.

7. In event of a waiting list, sign-ups are required to establish order of use.

8. Tool settings must not be altered without the permission of the NJIT laboratory Manager or a designee.

9. There must be no fewer than two people within easy hearing range of each other in the facility at the time of use.

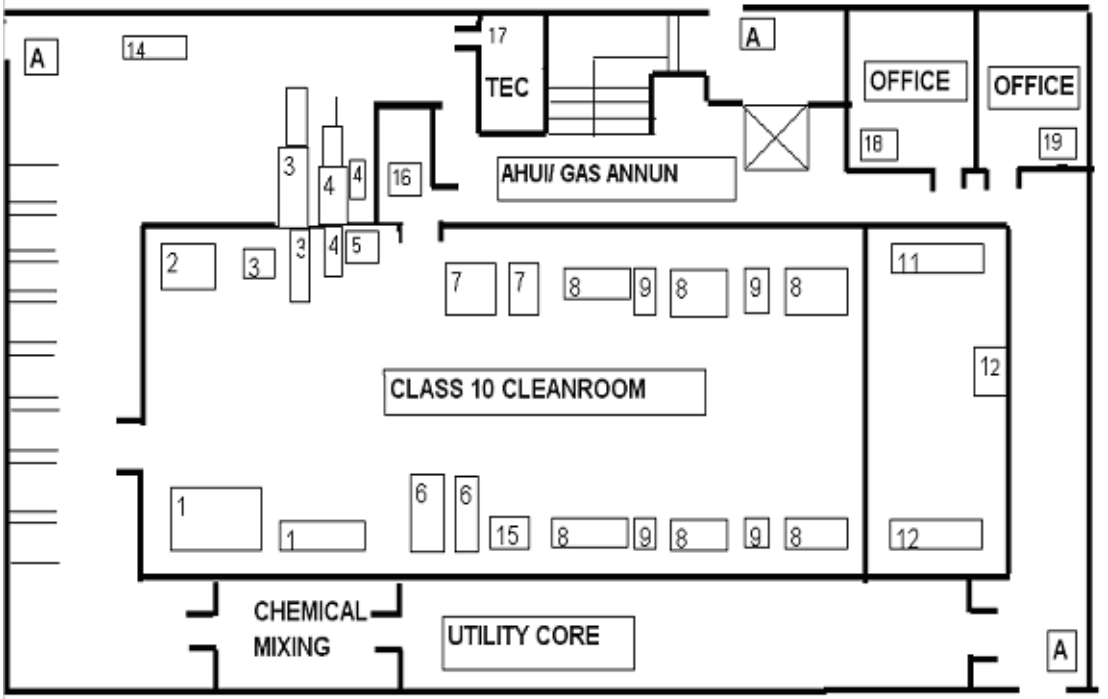
10. No Chemicals or equipment may be stored or used in the facility without written authorization from the lab manager. Chemical approval will be granted for specific quantities and concentrations only. Unapproved, improperly labeled and unidentifiable materials will be disposed of immediately.

11. When you complete your specific operation, the workstation is to be clean, free of clutter and ready for someone else to use.

12. When a specific operation (tool) does not function properly notify the NJIT laboratory manager or designee. DO NOT attempt to repair tooling.

1.3 NJIT CLEANROOM FLOOR PLAN

INTEGRATED CIRCUITS PROCESSING LAB MICROELECTRONICS RESEARCH CENTER



LEGEND

A FIRE ALARM

1. WAFER ALIGNER AND WAFER BONDER
2. DC SPUTTERING SYSTEM
3. DIFFUSION FURNACE BANK
4. LPCVD REACTORS
5. WAFER STATION
6. REACTIVE ION ETCH STATIONS
7. WAFER INSPECTION STATIONS
8. WET CHEMICAL WORK STATION
9. SPIN DRYERS
10. OXYGEN PLASMA ASGER
11. LITHOGRAPHY ALIGN AND EXPOSE
12. WAFER HANDLING ROBOT – PHOTORESIST INSPECTION
13. FILM THICKNESS MEASUREMENT
14. TUBEWASH STATION
15. GAS CABINETS
16. GOWNING ROOM
17. FACILITY ENGINEER
18. PROCESS ENGINEER
19. FACILITY MANAGER

1.4 Tool Usage Procedure

Only approved individuals whose name appears on each equipment list may operate that particular tool. All work must be approved each time prior to use of equipment and directed by staff personnel.

- Provide detail recipe for process run
- Obtain approval for run from NJIT Lab personnel
- Verify you are on the list of authorized personnel
- Fill out run log

Note: Do not tamper with any equipment that you have not been approved to use; research equipment shall not be disturbed.

2.0 CLEANROOM EVACUATION

2.1 Evacuate the Cleanroom When:

- Power failure occurs
- Hydrogen alarm sounds (loud bell)
- Exhaust failure alarm sounds (loud bell)
- Fire alarm sounds (loud horn)
- Hazardous gas leaks occurs or Hazardous Gas Alarm sounds (loud bell)
- Chemical spill on cleanroom floor

2.2 Evacuation Procedures

- Leave cleanroom as quickly as possible through nearest exit. Emergency exits are shown on facility layout. (See Section 1.3)
- Leave your classroom attire on. Do not take time to undress.
- Push the Emergency Stop Button for Air Handling Units (AHUI) as you exit. Stop button is located at the exit to the cleanroom (see facility layout). The AHUI is a unit that takes air from outside and circulates through HEPA filters.
- In case of a hazardous gas leak push the “red” abort button located outside the entrance to the cleanroom (gas annunciator panel). All gases will be shut off – (i.e. silane, dichlorosilane, ammonia, phosphine, chlorines, freons). (See section 1.3 for location)
- Make certain that no one is left in the laboratory by visually checking the photo area, chemical storage room and equipment chases. If necessary, call to anyone visible to evacuate lab.
- Follow proper calling procedures (see section 1.4) and dial Campus Public Safety (ext 3111)
- Contact authorized NJIT lab personnel.

DO NOT re-enter the laboratory until cleared by Campus Public Safety and/or NJIT Lab Personnel. The situation may warrant authorized NJIT personnel entering the lab wearing SCBA to correct the hazard. (SCBA = Self Controlled Breathing Apparatus)

***NOTE: Most process tools are equipped with alarms that do not warrant lab evacuation. However, always investigate tool alarms. Ask the NJIT lab personnel or refer to tool process specifications.**

3.0 EMERGENCY PROCEDURES

3.1 In Case of Controllable Fires

- Use the nearest fire extinguisher by
  - Pulling ring pin
  - Unclipping horn
  - Squeezing levers
  -Aiming at base of flames
- Use fire blankets to smother flames if clothing is on fire
- Turn source of power off in case of electrical fires
- Report fire to Lab Supervisor and Campus Public Safety (x3111)

3.2 In Case of Uncontrollable Fires:

- Leave cleanroom as quickly as possible through the nearest exit. Emergency exits are shown as facility layouts. (See section 1.3)
- Leave your cleanroom attire on. Do not take time to undress.
- Push the Emergency Stop Button for Air Handling Units (AHUI) as you exit except during power failure. Stop button is located at the exit to the cleanroom (see facility layout). The AHUI is a unit, which takes air from outside and circulates through HEPA filters.
- USE Fire Alarm Pull Stations. a) The pull stations are located at the exit to Microelectronics area (Faculty Hall hallway), b) at the exit to Summit Street, c) at the parking lot exit.
- Pull nearest alarm pull switch – fire alarm is a loud horn.
- In case of a hazardous gas leak push the “red” abort button located outside the entrance to the cleanroom (gas annunciator panel). All gases will be shut off – (i.e. silane, dichlorosilane, ammonia, phosphine, chlorines, freons) when the “red” abort button is activated.
- As you leave the cleanroom, make certain that no one is left in the laboratory by visually checking the photo area, chemical storage and equipment chases. If necessary, call anyone visible to evacuate lab.
- Follow proper calling procedures (see section 3.4) and dial Campus Public Safety (ext 3111).

3.3 In Case of Serious Accidents that require Immediate Medical Attention

- Call Campus Public Safety (ext 3111)
- NEVER MOVE OR LIFT AN ACCIDENT VICTIM UNLESS HE/SHE IS IN DANGER OF FURTHER INJURY. If he/she must be moved from a hazardous area, grasp his/her feet and drag him/her away while protecting – head from injury.
- Summon and wait for a trained person to arrive to give first aid. If immediate action is needed, one or more of the following may be done while waiting for first aid assistance.

  - Chemical Contact with Skin (except HF):

    20. Use emergency overhead shower located in cleanroom
    21. Remove contaminated clothing

22. Flush with copious amounts of water at least 15 minutes
23. Get medical attention, request assistance

- Chemical Contact with Eyes

1. Use emergency eye wash located in cleanroom
2. Rinse with eyewash at least 15 minutes, lifting upper and lower eyelids occasionally.
3. Get medical attention as quickly as possible regardless of how eyes feel; request assistance.

- Hydrofluoric Acid (HF) Contact with Skin (including HF mixtures)

1. Remove contaminated clothing
2. Rinse 15 minutes in cold water
3. Get medical attention

Caution: HF, while not likely to cause an immediate burn can cause delayed burns

- Electrical Shock

1. Call Campus Public Safety (x3111)
2. Remove the source of shock as soon as possible

- Bleeding

1. Call Campus Public Safety (x3111)

- Not Breathing

1. Call Campus Public Safety (x3111)

- Fractures

1. Call Campus Public Safety (x3111)

- Thermal Burns

1. Call Campus Public Safety (x3111)
2. Do not attempt to remove clothing

In all emergency situations act promptly but never hastily. Thoughtless actions may only complicate the situation.

- Report all accidents or injuries to Campus Public Safety (x3111) and NJIT lab personnel

3.4 When Calling Campus Public Safety

- Dial ext 3111
- Identify yourself

- State that the fire or accident occurred in Microelectronics Center, Summit Street
- State the telephone number of the phone you are using
- Tell the Dispatcher what is wrong as clearly and quickly as possible
- Do not hang up, stay on telephone to maintain constant communication

4.0 CHEMICAL SAFETY

4.1 Solvents

1. General: A solvent is any liquid used to dissolve another substance. In microelectronics, solvents are used in many processes, including degreasing, stripping, wafer production, and photolithography. Workers are exposed to solvents mainly by breathing and skin contact. Each solvent has its own unique properties and health hazards, but some generalizations can be made:

    - Solvents can cause acute damage to skin and breathing passages.
    - Most solvents can enter the blood stream after inhalation
    - Most solvents are highly inflammable; some are explosive.

    - Long term exposure to even low levels can cause a variety of organ damage. Liver, lung, kidney and reproductive organs can be damaged from low-dose exposure. In addition, infertility in women and men, damage to the unborn, and cancer (caused by exposure to benzene and chlorinated hydrocarbons) can result.
    - The health affects of long-term exposure and interactions of solvents with other chemicals may not be known in detail. Some solvents once thought to be safe (e.g. benzene) are now known to be powerful carcinogens. Therefore, solvents should be treated as potentially harmful. Adequate ventilation, safe storage and protective clothing are among the safety measures that must be used.
    - It is always important to know that you are working with and to be aware of potential problems. Consult the MSDS (Material Safety Data Sheets) located inside and outside the cleanroom.
    - Solvents located in the laboratory at NJIT are listed in Appendix A along with their basic hazards. The approved chemicals for each hood location are listed in Appendix B. Only these approved chemicals should be used in particular hoods.

2. Personal Protective Equipment (PPE) should be worn when pouring or mixing with all solvents and photolithographical chemicals:

    - Safety glasses/ goggles
    - Face shield
    - Chemical gloves
    - Chemical aprons
    - Closed-toe shoes

    When processing wafers the following should be worn:

    - Cleanroom attire (section 1.1.1)
    - Safety glasses

- Chemical gloves
- Closed-toe shoes

NOTE: ALWAYS USE IN VENTILATED HOODS! NEVER INHALE VAPORS!

4.2 Acids and Bases

1. General: Acids and bases (alkalines) are used in a variety of processes in the microelectronics industry. Acids are used to clean wafers, etch wafers, and clean quartzware. Bases are used in photolithographical processes and in etchant solutions.

    - All Acids can cause injury (burns) when splashed on the skin or in the eyes. Vapors or mists from a solution cannot only injure the eyes, but also the mucous membranes and respiratory system. The extent of the injury can be dependent on the strength and type of acid being used and length of exposure. Effects on the skin range from mild rashes to severe blisters and ulcers (breaking through the skin). Effects on breathing range from irritation in the breathing passages to chronic bronchitis to pulmonary edema (fluid in the lungs). Long-term effects of exposure and interactions with other chemicals are largely unknown. At least one cancer-causing agent is formed when chromic acid comes in contact with metals.
    - In the event of a splash or spill, the exposed skin or eyes should be flooded with water under an emergency shower or eyewash for 15 minutes. If acid splashes on clothing, remove clothing under shower.
    - Call Campus Public Safety (x 3111)
    - Acids located in the laboratory are listed in Appendix A with their hazards.
      Material Data Safety Sheets (MSDS) are also located at the entrance of the cleanroom for additional information on these chemicals.
      Only approved chemicals should be used in the particular hood locations as listed in Appendix B.
    - Bases can cause injury (burns) when splashed in the skin or in the eyes. Vapors or mists from the solution can not only injure the eyes, but also mucous membranes and respiratory system. Due to the permeating nature of alkalis, severe eye injuries can still happen with even a dilute alkali solution.
    - Effects on the eyes include cataracts and glaucoma. Effects on the skin range from mild rashes to severe blisters and ulcers. Alkali burns are usually more severe than acid burns. Effects on breathing range from irritation in the breathing passages to chronic.
    - In the event of any exposure to eyes, rinse with water for 30 – 60 minutes. Any exposure to skin should be flooded with water under an emergency shower or eyewash for 15 minutes. If bases splash on clothing, remove clothing under showers.
    - Call Campus Public Safety (x3111)
    - Bases located in the laboratory are listed in Appendix A with their hazards.
    - Materials Safety Data Sheets (MSDS) are also located at the entrance to and in the cleanroom for additional information on these chemicals.

2. Only approved chemicals should be used in particular hood locations as listen in Appendix B.

3. The following personal protective equipment should be worn when pouring, missing or processing wafers with any acid or base:

- Cleanroom attire
- Safety glasses/ goggles
- Full face shield
- Chemical gloves
- Chemical apron
- Closed-toe shoes

NOTE: When working at or near acid hoods, always wear chemical gloves. Beware of any objects or controls on the interior or exterior of the hoods as they are likely to have been handled by someone with acid on his gloves.

4. The MSDS (Material Safety Data Sheets) are located at the entrance and inside the cleanroom**.** This book lists the properties of the chemicals that are used in the cleanroom.

4.3 Oxidizing and Reducing Substances

1. General: In any reaction of this type, both agents must be present. Usually, one or the other creates a hazard by coming in contact with a normally innocuous substance.
Oxidation-Reduction (Redox) reactions can occur in any of the three physical states (gas, liquid or solid). The reactions tend to generate heat and are often explosive.

2. Precautionary Measures: In general, isolate from other potentially reactive compounds. Use adequate personal protective equipment when working with such agents. If the substances are not water-sensitive, safety showers, sprinkler systems should be made available.

3. See Appendix A for list of oxidizing and reducing substances

5.0 CHEMICAL STORAGE, HANDLING, WASTE DISPOSAL, SPILLS AND HOOD OPERATIONS.

5.1 Storage

- Never store any acid or any solvent in the same cabinet or hood. An explosion could occur. (See Appendix A for incompatibilities)
- Only store chemicals in properly designated cabinets or hoods. (If there is any doubt about their proper locations, ask NJIT lab personnel.)
- All containers must be labeled as to their contents. Otherwise they will be disposed of and their owners suspended from the cleanroom.
- Only chemicals approved by the Lab manager may be stored in the lab (See Appendix A for approved list)
- Photolithographical chemicals are treated as an exception (See Appendix E for storage instructions)

5.2 Handling

- Always know the dangers before handling any chemical. Read the Material Safety Data Sheet or refer to Appendix A in this manual.
- Always wear proper protective attire, even if only carrying a bottle from the storage cabinet to a hood.
- Use bottle carrier for any glass container.
- Never carry acids and solvents together.
- Verify hood is available and all equipment needed is present prior to bringing chemicals.
- Open chemical bottle only inside exhausted hood.
- Wipe acid bottle exterior after pouring. First with wet lint-free towels and then dry towels. Rinse towels with DI water before disposing in plastic-bad-lined safety container (acid contaminated rags unrinsed present a fire hazard).
- When working with acids and solvents, rinse chemical gloves periodically with water and dry with lint-free towels.
- Take great care to avoid touching any equipment with contaminated gloves or garments.
- Always rinse gloves and hands with DI (Deionized) water after handling chemicals.

5.3 Waste Disposal

1. Disposal of “empty” bottles

    - Acids – triple rinse interior of empty bottles and rinse exterior in proper acid drains before discarding or use bottle washer in general sink.
    - Solvents – “Empty” solvent bottles must be vented in the general sink at least 12 hours before discarding. Mark on bottles date and time bottle is to be removed and initial. Recap aerated bottle and discard.

2. Acids and Bases

    - Use aspirator for draining acids in designated acid drains; never use industrial or water drains
    - Rinse acid tanks after aspirating and aspirate empty tanks twice with DI water
    - Clean area around acid tanks after emptying tanks or completing an operation. Use wet lint-free towels and then follow with dry lint-free towels.
    - Rinse towels thoroughly with water before discarding in plastic-bag-lined safety disposal can.

3. Solvents

    - Never return spent solvents to original containers.
    - Solvent waste containers are stored in photo area.
    - Contents of solvent waste are not to be mixed with other solvent waste.
    - Chlorinated solvent waste is not to be mixed with other solvent waste.

- Photolithographical chemicals should be disposed of by following the procedure in Appendix E.
- Solvent waste pick-up is to be arranged with Campus Hazardous Waste

CAUTION: Any chemical spill presents an immediate safety hazard. Clean-up should be immediate.

5.4 Clean Up

1. Inside Hoods

a) Chemical
- Rinse work surface with DI water spray
- Notify lab personnel

b) Solvents
- Eliminate any source of ignition or sparks (such as hot plate)
- Use solvent pillows to absorb spill
- Place solvent pillow in plastic bag and label
- Notify lab personnel for disposal

2. Outside Hoods (over 500 cc)

- Evacuate area immediately
- Shut off AHUI using emergency stop button
- Notify NJIT lab personnel
- Call Campus Public Safety Office (ext 3111)
- Do not re-enter cleanroom until cleared by authorized NJIT personnel or by Campus Public Safety.

5.5 Chemical Hood Operations

Acid and solvent hoods are considered process equipment or tools. The NJIT Lab protocol and general rules must be followed for any chemical hood operations.

1. Proper personal protective equipment must be worn (See Section 4.1.2)

2. Only specifically approved chemicals may be used for approved operations conducted in a particular hood (See Appendix B)

3. Never touch the interior or exterior of chemical hoods with bare hands due to the possibility of chemical residue.

4. Ensure DI (Deionized) water, N2 bubbler, acid siphon, hot plates and spin dryers are off when work is complete. Follow posted shut down procedures.

5. Never submerge gloves in acids or solvents (pinholes are sometimes present)

6. Do not touch anything away from chemical hoods with gloves. Hood controls may be touched after rinsing and drying gloves.

7. Carefully remove protective clothing to ensure no exposure to the exterior of contaminated garments. Solvent waste must be separated from acid waste.

8. DO NOT USE SOLVENTS IN ACID HOODS OR ACIDS IN SOLVENT HOODS. An explosion might occur.

9. In Case of fire in chemical hood, refer to section 3.1, 3.2 for procedure.

6.0 COMPRESSED GASES

NOTE: Arrangements must be made with NJIT lab personnel before handling any pressurized gas cylinders. Only authorized NJIT lab personnel will handle hazardous gases.

6.1 General

Compressed gases represent a special hazard. Each compressed gas cylinder contains a very large amount of energy. This energy, released improperly, can result in serious injury. In addition, the gases can be hazardous for their inflammability, toxicity or corrosiveness. (See Appendix A)

6.2 Precautions

The following is a list of precautions that should be followed in order to minimize hazards associated with any compressed gas.

1. All gas cylinders, whether full or empty, shall be handled using the proper equipment and personal protective equipment.

2. Do not transport gas cylinders without valve protection cap in place unless properly mounted for use on service carts.

3. Do not use cylinders as rollers or support.

4. Close valves tightly following use.

5. All cylinders are to be secured with the approved holders and straps.

7.0 Cryogenic Fluids

7.1 General

Cryogens such as liquid nitrogen and helium are used in cold traps for vacuum systems. The tools at NJIT that use cryogenic fluids are the Evaporators, Sputter Systems Detector.

7.2 Hazards

Explosion, spillage, frostbite and escape of asphyxiating gases are some of the more common hazards.

7.3 Handling

Only authorized personnel will service equipment requiring cryogenic fluids. However, for any exposure or short period of contact with cryogenic fluids, flush area of exposure with large quantities of warm water.

Seek medical attention; call Campus Public Safety (x3111).

When pulling off liquid, gloves and face shield will be worn.

8.0 PHYSICAL HAZARDS

8.1 Radio Frequency (RF)

Reactive Ion Etchers and Plasma-assisted growth systems all generate frequencies between 10 MHz and 100 GHz. These tools are properly shielded. Precautions to follow are:

- Keep face and limbs away from any exposed induction coils

- People with pacemakers should not enter the area.
- HIGH VOLTAGE is present. Do not touch tool unless completely qualified for usage.

8.2 Thermal

The two diffusion furnaces at NJIT operate between 400 C and 1300 C. Therefore:

- Never put your face or limbs in or close to the tubes.
- HOT quartzware looks like COLD quartzware. Never touch without CAUTION.

8.3 Ultraviolet Lights (UV)

Mask aligners in the photolithography area operate a mercury arc lamp, which emits UV light. Be sure to:

- Never allow direct radiation from lamp to hit the eyes.
- Never place a white or metallic reflective surface where it may reflect into your eyes.
- Never place flammable material in optical path of the mercury lamp.

CAUTION: Allow mercury lamp to cool at least 30-45 minutes before removing the amp house for ANY reason. Mercury lamp will explode if not cooled.

8.4 Lasers

Precautions with tools using LASERS:

- Ionizing radiation exposure hazard present.
- High voltage hazards
- Hazards in explosion of gas tubes.

APPENDIX A
CHARACTERISTICS OF APPROVED CHEMICALS

Chemical	**Properties**			
Acetic Acid handle like a solvent Organic Acid	Vinegar HAc CH3COOH	Corrosive, irritant, may cause burns. Do not induce vomiting	Moderate keep away from oxidizers like peroxides and nitric acid	Pungent odor, vinegar
Acetone Solvent	Dimethyl Ketone (CH3)2CO	Defats skin, mild irritant, less toxic than most solvents	Dangerous, Keep away from sparks and ignition	Fragrant, mint-like odor. Highly volatile
Accustrip P-300 Organic Base	Piperazines N-methylpry-rolidone	Corrosive, irritant, may cause burns. Do not induce vomiting	Moderate, Thermal decomposition, Products include carbon monoxide	Slight amine-like odor. Light yellow colorless liquid.
Aluminum Etch Acid	H3PO4 79% CH3COOH 5% HNO3 5% H2O 11%	Corrosive, irritant can cause burns	Low	Pungent odor of vinegar
Ammonium Fluoride Salt	NH4F	Highly toxic, chronic exposure may result in damage to bones and teeth	Non – flammable but may release NH3 at fire temperatures	Colorless crystals, soluble in water used in heavy viscous solution in lab
Ammonium Hydroxide Base	NH4OH Aqua Ammonia	Irritating, caustic to skin, eyes, do not induce vomiting	Low, separate from oxidizing agents	Good warning properties, ammonia
Ammonium Peroxydisulfate Oxidizer and Base	(NH4)2	Highly irritating	Keep away from flammable materials, Strong oxidizer	White crystals

Argon Gas	Ar Inert gas	DOT asphyxiating in concentration	Colorless odorless non-flammable	Gas
Arsine Gas	Arsenic hydride AsH3	Highly toxic, lethal gas, attacks red blood cells causes anemia, kidney damage, red urine, nerve damage	Moderate when exposed to flame; very high when gas mixture contains hydrogen	Mild garlic odor, colorless
BOE Buffered Etch Acid	Oxide etch NH4F, HF	Skin contact, dangerous, see hydrofluoric acid in a fire	Non-flammable, but will release corrosive vapors	Rinse any suspected skin or eye contact with water
Boron Trifluoride Gas	Boron fluoride BF3	Highly corrosive, strong irritant, reacts with moisture to emit corrosive vapors, causes chemical pneumonia	Non-flammable	Colorless, pungent, Suffocating odor
n-Butyl Acetate Solvent	Butyl Ethanoate CH3COOC4H9	High concentration may cause drowsiness	Moderate, keep away from oxidizers	Odor is detectable below hazardous levels
Carbon Dioxide Gas	CO2 Carbonic acid gas, dry ice	Headaches, dizziness, increased heartrate, coma, asphyxia, convulsions	Not combustible, good extinguishing agent	Colorless liquid
Cellosolve Acetate Solvent	Ethylene glycol, mono-butyl ether acetate, 2-butoxyethyl acetate	Absorbs through skin may cause damage to blood, kidneys, and liver	Moderate	

Chlorine Oxidizer	Cl2	Burns eyes, nose, mouth, etc. can cause nausea, choking, vomiting, pneumonia, pulmonary edema	Not combustible	Amber liquid or greenish-yellow gas, irritating odor; liquid bleach
Deionized water Oxidizer	D-I water	Bacteria may breed in D-I water	None	Avoid skin contact (except in an emergency) and drink
Diborane Gas	B2H6	Highly toxic, causes irritation to pulmonary, temporary damage to kidneys and liver	Flammable, Use protein-base foams to extinguish fires- never water	Colorless, sickly sweet odor
Dichloro-silane Gas	DCS SiH2Cl2	Psyrophoric, highly corrosive, treat like silane	Flammable liquefied gas	Colorless, suffocating odor
Ethanol Solvent	Ethyl alcohol Grain alcohol C2H5OH	Normally not very toxic via inhalation. May cause drowsiness, headache	Dangerous – keep away from sparks and ignition sources	Sweet pleasant odor
Ethylene diamine Solvent	Ethylene diamine NH2CH2CH2NH2	Respiratory irritant, sensitization dermatitis, causes asthma, liver and kidney damage	If heated emits nitrogen oxides	Colorless liquid or solid with an ammonia like odor
Ethylene Glycol Solvent	Glycol alcohol CH2OHCH2OH	Not a significant inhalation or skin contact hazard. May cause severe kidney damage if ingested	Slight	Contained in antifreeze

Freons Gas	Fluorocarbons	Defats skin, May cause dermatitis, may be irritating. May emit toxic vapors when heated to decomposition	Slight	Colorless
Freon TF Solvent	Trifluorotri-Chloroethane CCl3CF3	Defats skin, irritating to eyes. Higher concentrations may cause dizziness	Slight, avoid open flames. Decomposition products – HCl, HF and phosgene	Environmental concern with freons ethereal odor
Helium Gas	He	May be asphyxiating in very high concentrations	Non-flammable	Colorless, odorless, lighter than air
HMDS Solvent (Strong Base)	Hexamethyl-disilasane	May cause irritation, headache or dizziness	Moderate	Ammonia-like odor, colorless. Contact with water may release ammonia
Hydrochloric Acid Acid	Muriatic acid Hydrogen chloride HCl	Corrosive, irritant, may cause burns, do not induce vomiting. Keep away from oxidizing agents	None	Biting odor, colorless
Hydrochloric Etch Acid	Hydrochloric acid, Ferric chloride	Corrosive, irritant, may cause burns	None	Biting Odor
Hydrofluoric Acid Acid	Hydrogen fluoride HF	Skin or eye contact extremely dangerous. Nothing is felt at first but after latent period, excruciatingly painful tissue and bone	Releases toxic fluoride vapors when heated, corrosive	Rinse any suspected skin or eye contact with water. Seek medical attention

		destruction may occur and may take months to heal		
Hydrogen Gas	H2	Very slight asphyxiant	Highly dangerous, may explode or burn in contact with Oxygen. DOT flammable	Colorless, odorless, lighter than air
Hydrogen Peroxide Oxidizer	Hydrogen dioxide H2O2 Peroxide	Depending on its concentration it can be severely irritating and can cause severe burns	Dangerous, powerful oxidizer. Keep away from solvents and combustible material, store one year only	Heavy liquid, Acrid odor
Isopropanol Solvent	Isopropyl alcohol 2-propanol C2H4OHCH3	Irritant, nervous system depression at higher concentrations, not a significant toxic hazard	Dangerous flammable, Keep away from oxidizers	Slight sweet odor
Krypton Gas	Kr	Simple asphyxiant if liquid causes frostbite	DOT non-flammable	Inert, colorless, odorless, tasteless
Mercury	Quicksilver Hg	High systemic toxicity, affects nervous system. Absorbs though skin	Low	Silvery, metallic liquid. Report any spills or broken thermometers
Methanol Solvent	Methyl alcohol Wood alcohol CH3OH	Absorbs though the skin. May cause headache, dermatitis, visual problems, narcosis, can cause blindness or	Dangerous keep away from oxidizers	The antidote for ingestion is ethyl alcohol; colorless

		death		
Methyl Ethyl Ketone Solvent	MEK 2-butanone CH3COCH2CH3	Narcotic, irritant	Dangerous flammable	Characteristic clear liquid
Nitric Acid Acid Oxidizer	Aqua fortis HN03	Corrosive, irritant, may cause burns, stains skin yellow	Oxidizing material, keep away from flammable and finely divide metals	
Nitrogen Gas	N2	May be asphyxiating in very high concentrations . Liquid nitrogen may cause frostbite or cold burns	None	Colorless, odorless
Nitrogen Dioxide Oxidizer and Gas	Oxides of nitrogen NO1 ,NO2 , NP, etc	Irritation of eye, nose and throat, delayed pulmonary edema, NO2 ,is highly toxic	Keep away from combustible materials, oxidizing	Brown and odorless gas
Nitrous Oxide Gas	N2O laughing gas	Anesthetic, simple asphyxiant	Moderate, supports combustion, can form explosive mixture	Colorless, in case of prolonged laughter, leave the area
Oxygen Gas	O2	None, as a gas. As a liquid, may cause burns	High, supports combustion	Colorless, odorless
Phosphine Gas	Hydrogen phosphide PH3	Lethal gas, very toxic, affects on central nervous system and lungs, irritating,	Dangerous, extremely flammable in air	Colorless, smells like rotten fish

		bollod poison		
Phosphoric Acid Acid	H3PO4	Corrosive, irritant, may cause burns, vomiting	May emit toxic vapors if heated to decomposition	Clear, syrupy liquid. Odorless
Phosphorus Oxychloride Corrosive	POCl3 Phosphoryl chloride. “pockle”	Intense irritant, can cause sever burns. Reacts violently with moisture to form corrosive vapors	Noncombustible corrosive. Keep away from water	Colorless to slightly yellow fuming liquid. Keep away from water or moisture
Photoresist-negative Solvent	KTI, xylene and Cellosolve acetate	Absorbs through skin, irritant, narcotic, systemic toxin	Dangerous	
Photoresist-positive Solvent	AZ 1350J 70% Cellosolve acetate 10% n-butyl acetate 5% xylene	Absorbs through skin irritant and systemic toxin	Moderate to Dangerous	Red-purple color. Odor is detectable below hazardous levels
Positive Photoresist Developer Solvent	AZ developer, mild alkaline solution	Irritating to skin, eyes and lungs	None	Amine-like odor
Potassium Hydroxide Base	XOII	Highly corrosive to skin and eyes	Low	Rinse any skin contact well
Propanol Solvent	1-Propanol Propyl alcohol CH3CH2CHOH	Irritant to eyes, mucous membranes and skin. Narcotic at high concentrations	Dangerous	Sweet odor

Silane Gas	SiH4	Exposure unlikely due to spontaneous combustion	Extremely flammable. Small leaks can ignite spontaneously in air	
Silicon Tetrachloride liquid Corrosive	Silicon chloride SiCl4	Severe irritant, emits toxic vapors when heated, do not mix with moisture	None	Suffocating odor, colorless liquid
Silicon Tetrafluoride Gas	SiF4			
Sodium Hydroxide Base	NaOH, Lye, caustic soda	Highly corrosive to skin and eyes. Hydrogen gas if contact with Al, 5n	Low	White pellets, odorless
Sulfuric Acid Acid	Oil of vitriol H2SO4	Causes severe burns to skin and eyes	May cause spontaneous ignition of combustible materials	Mixing with water creates heat, so add to water slowly

APPENDIX B
APPROVED CHEMICALS USAGE

Approved Chemical – PR Removal and Metal Etch

- Sulfuric Acid – H2SO4
- Aluminum Etch
- Phosphoric Acid – H3PO4
- Nitric Acid – HNO3
- Hydrofluoric Acid – HF
- Trinitron X-100 – Detergent/Surfactant
- Ammonium Fluoride – NH4F
- Ethylene Glycol – CH2OHCH2OH
- Ammonium Peroxydisulfate – (NH4)2S2O8
- Buffered Etch
- Acetic Acid – CH3OH
- Ammonium Hydroxide – NH4OF
- Hydrochloric Acid – HCl
- Potassium Hydroxide – KOH
- Trans- Etch – N

Approved Chemicals – Pre-Diffusion Clean

- Ammonium Hydroxide – NH4OF
- Ammonium Peroxydisulfate – (NH4)2S2O8
- Buffered Etch
- Hydrochloric Acid – HCl
- Hydrofluoric Peroxide – H2O2
- Sulfuric Acid – H2SO4

APPENDIX C
FURNACE AREA

Operations

Wet and dry thermal oxidation. Predisposition and drive-in of dopants and thermal annealing. See the diffusion specification for reference.

Gases and Chemicals Used

Oxygen (O2), Nitrogen (N2) and Phosphorous Oxychloride (POCL3 or “Pockle” – liquid or vapor), TMP (Trimethyl Phosphate)

General Hazards

Flammable, explosive and toxic gases present. High temperatures (up to 1300 degrees), high voltages and potential for sharp flying objects.

Special Note:

This is not an operating specification. Additional certification and training will be needed to experiment with or operate this equipment.

General Safety

1. The NJIT Lab Protocol and General Lab Safety rules must be followed. See Sections 1.0 and 2.0.

2. Never touch hot boats, wafers, sleds or the ends of furnace tubes even if you are wearing rubber gloves. They can be microscopically contaminated.

3. High Voltage is present in the furnace electrical cabinet located at the bottom of the furnace cabinet. Do not open this cabinet unless power is off and you are authorized for high voltage.

4. H2, HCl, or POCL should NEVER be FLOWING while the furnace tube is open

    a. H2 is a flammable explosive gas with no odor. H2 detectors are located in the furnaces, gas cabinets and gas cylinder cabinets. If H2 is detected, a loud bell will ring (same as exhaust failure alarm). In this event evacuate the lab. Shut off at hazardous gas and Shut off AHUI. Sound fire alarm.

    b. HCl is a corrosive gas, which causes acid burns when breathed or contacted with skin or eyes. HCl has an irritating odor somewhat similar to that of chlorine bleach. In case of large HCl leak, evacuate the lab.

    c. POCL is a liquid with a musty pungent odor. Its vapors are dangerous to breathe. If liquid POCL comes in contact with skin, eyes or clothing treat as an acid, remove contaminated clothing before using water to rinse skin.

5. There are shut off valves for each gas at rear of the furnace gas control panels. N2 or O2 can also be shut off above rear of the furnace gas cabinet. The main shut off valves for the other gases are located in the gas cylinder

cabinets, be familiar with these locations and operations – a major disaster may be prevented.

APPENDIX D
LPCVD System Safety

Operations: Silicon, Nitride, silicon dioxide and polysilicon depositions. Thermal annealing and oxidation are performed in the top tubes of each console. See the diffusion specifications for reference.

Gases Used

Ammonium (NH_3), Argon (Ar), Oxygen (O_2), Hydrogen Chloride (HCl), Nitrogen (N_2), Silane (SiH_4), Nitrous Oxide (N_2O), and Dichlorsilane (SiH_2Cl_2). (See Appendix A for gas properties and precautions)

General Hazards: Flammable, explosive and toxic gases present. High temperatures, high vacuums, high voltages, potential for sharp flying objects. (See Appendix A for gas properties and precautions)

Special Note: This is not an operating specification. Additional certification and training will be needed to experiment with or operate with this equipment.

General Safety

1. The NJIT lab protocol and General Lab safety rules must be followed.

2. Do not touch any boat or loading system with gloves or hands even if you are certain it is cool. The operating temperature ranges from 500^{o} to 1300^{o} .

3. Ensure N_2 pressure on vacuum pumps reads 50 SCFM on gauge while idling and 100 SCFM during deposition. Nitrogen is used to purge pumps and prevent pump or exhaust line explosions due to high concentrations of explosive gases.

4. HCl will corrode plumbing when exposed to air. Leaks create white or brown powder around stainless steel joints where the leak occurs. A very small leak will generate a strong irritating odor throughout the area. If a small leak is suspected turn off HCl at the bottle regulator immediately as HCl leaks will increase in size as corrosion continues. Contact an NJIT staff member as soon as possible. In case of a large HCl leak (strong odor of HCl) evacuate the lab immediately and turn off air handlers, hazardous gas shut off and sound the fire alarm.

5. Silane is a very dangerous gas. It ignites shortly after exposure to air producing water vapor and silicon dioxide powder (white). High Temperature. If a line rupture occurs, DO NOT turn off the gas vacate the lab and turn off air handlers and hazardous gas shut-off on outside lab. Sound fire alarm.

6. Dichlorosilane self-ignites after contact with air producing HCl, explosive and dangerous. If a line rupture occurs, immediately vacate the entire lab. DO NOT turn gas off. Once outside, turn off air handlers and hazardous gas via emergency shut-off. Sound fire alarm.

7. Nitrous oxide is a colorless, odorless, but noxious gas. See Appendix A for the gas properties. If a small leak is suspected, turn the gas off at the bottle and vacate the lab for at least an hour. If a large leak is suspected, vacate the lab.

8. Ammonia is a colorless, pungent odor gas. Highly irritating to skin, eyes and respiratory tract. If a small leak is suspected, turn off at the bottle and vacate lab. If a large leak, evacuate lab immediately and turn off air handlers and hazardous gas shut-off. Sound the fire alarm.

APPENDIX E
PHOTOLITHOGRAPHY AREA

General Processing Precautions

Wear full safety apparel during all photolithography operations:

1. Safety glasses/goggles
2. Vinyl Gloves

Process Steps

A. Spinning (Apply Photoresist)

1. Chemicals used: (Adhesion Promoter)
   a) Ingredients: Hexamethyldisilazane (HMDS)
   b) Brand Names:
   c) Microposit Primer (Shipley)
   d) 100% HMDS (various vendors)
   e) Chemical mixture concentrations
      100% HMDS

2. Handling precautions
   a) Avoid contact with eyes and skin
      i. Do not touch skin or rub eyes during or after handling primer from bottle. Gloves may be contaminated with primer
      ii. May cause burns
      iii. If eye contact, flush with water for 15 minutes; seek medical attention.

3. Photoresist: (Polymer and sensitizer)
   a) Brand Names
      i. Shipley Microposit (1800 and 3800 series)
      ii. AZ Positive Photoresist (1300 & 400 series)
      iii. Others

4. Handling Precautions:
   a) Avoid contact with skin and eyes
      i. Do not touch skin or rub eyes during or after photoresist spinning; gloves may be contaminated.
      ii. If eye contact, flush with water at least 15 minutes. Seek medical attention.
      iii. If skin contact, wash affected areas with soap and water
   b) Avoid breathing vapors
      i. If inhaled, move into fresh air
      ii. High concentration of vapors are irritating to eyes and respiratory tract and can cause narcosis (deep stupor and unconsciousness)

5. Equipment Material Compatibility
   a) Stainless Steel
   b) Glass
   c) Ceramic
   d) Polypropylene

e) Polyethylene
f) Teflon
g) Nylon

6. Storage
   a) Store only in original containers
   b) Store sealed bottles away from oxidants, light, heat, sparks, or open flame.
   c) Store at temperatures of 15 – 17°C (59 - 63°F); never above 27° C (80° F). (In refrigeration provided)
   d) Do not store photoresist bottles for more than <u>one year</u>.
      i. Label all bottles with date upon receipt in lab.
      ii. Pressure builds up slowly in closed containers due to gradual decomposition of materials.
      iii. Decomposition is accelerated by heat and light with possible liberation of combustible solvent

7. Disposal
   a) During spinning, ensure that photoresist drain line is connected from spinner cup to labeled photoresist waste container under photoresist spin module.
   b) Disconnect the photoresist waste container from the drain line when it is approximately ¾ full.
      i. Cap the used waste container and leave under hood until removed by authorized personnel.
      ii. Contact Lab personnel to make disposal arrangements
      iii. Install new photoresist waste container under the photoresist spin module.
   c) Do not pour any photoresist waste into drain.
   d) Rinse empty photoresist bottle with a small volume of acetone to remove photoresist residuals.
      i. Carefully pour acetone-photoresist waste into under-hood waste container or solvent drain. (Solvent drain is located in chemical mix area).
      ii. Aerate uncapped bottle 12 hours. Label date/time for removal; initial.
      iii. Recap bottle and dispose of in trash container.

8. Spills – follow procedures outlined in this manual.

9. Fire:
   a) Extinguishing media
      i. Halon
      ii. Carbon Dioxide
      iii. Water Spray
   i. Cool containers near fire with Halon or carbon dioxide
   ii. Use self-contained breathing apparatus if necessary, toxic fumes may be emitted.

B. Photoresist Module Cleanup Procedure

1. Use clean-up solvent (acetone) to remove photoresist spills and splashes from equipment top and to clean the photoresist spinner cup assembly. Note:

Acetone is a flammable solvent. Safety precautions concerning use of solvents should be observed.
2. The area should be well ventilated before use of clean-up solvents.
3. Wear approved chemical gloves. Dispensable nylon and vinyl gloves are attached by acetone.
4. Photoresist waste solids (lint-free towels and disposable garments) should be placed in plastic waste bags and the bags tied and labeled.
5. Contact lab personnel to make disposal arrangements.

C. Photoresist Develop

1. Chemicals used:
   a) Ingredients
      i. Vendor-proprietary formulations
      ii. Solutions of ingredients such as Tetramethylammonium hydroxide (25%)

   b) Brand names
      i. Microposit 312, 315, 35,352,450 (Shipley)
      ii. AZ 312 MIF, 351, AZ Developer (AZ)
      iii. Others

2. Handling Precautions

   NOTE: Many developers are corrosive alkaline solutions. For general safety purposes, all developers will be considered as such. Read the specific label on each developer bottle.

   a) Avoid contact with skin and eyes
      i. If eye contact occurs, flush with water for 30 – 60 minutes; seek medical attention
      ii. If skin contact occurs, flush with water for 15 minutes
   b) Avoid breathing vapors. If inhaled, move into fresh air.

3. Equipment material compatibility
   a) Polypropylene
   b) Polyethylene
   c) Teflon

4. Storage
   a) Store in original containers at 10 – 32^{o}C (50 – 90^{o}F)
   b) Flush with water

5. Disposal
   a) Dispose of developer wastes in general hood waste
   b) Flush with water

6. Spills: Follow procedure outlined in this manual

7. Fire: developers are non-flammable and will not react with extinguishing media.