WORK ACCEPTANCE, APPROVAL AND AUTHORIZATION

PART I: WORK ACCEPTANCE

Short Project/Activity Name:

Center for Integrated Nanotechnologies User Program/Integration Laboratory

Primary Customer Contact Information:

Customer Organization: DOE-Scientific User Facilities

Contact Name/Position/Role: Dr. George Maracas: DOE-SUF

Phone: Email:

Roles and Responsibilities:

Technical Point of Contact/Work Planner: John Nogan, Department-1132, 284-8863, jnogan@sandia.gov

Work Description:

Since this was an existing laboratory with ongoing programs, this AAA form represents all the activity level work being performed in Building 518/Integration Laboratory. The primary focus of the work performed in the Integration Laboratory is the fabrication of a variety of nanostructured materials and devices, as part of the Center for Integrated Nanotechnologies User program. The CINT Integration Laboratory is a 9000 sq. foot class 100 cleanroom micro/nano fabrication facility. The facility instruments can accommodate samples as large as 100mm diameter wafers. Individual feature sizes as small as 20 nm can be fabricated using e-beam lithography. The facility tool sets range from plasma deposition and etching to focused ion beam nano-fabrication. The Integration Laboratory is staffed by a team of process engineers with over 60 years of combined micro-processing experience. Access to the Integration Laboratory tool sets is obtained via the CINT User program. The Integration Laboratory is supported by the DOE-BES-Scientific User Facilities program (Project 146433).

Facilities/Laboratories/Locations:

Building 518, Integration Laboratory

Clearance/Badges/Access Required

Not Required/Sandia Site badge

Compare Proposed Work to Approved Operating Envelope/Safety Cases:

Does the scope, hazards, and controls for this work fall within the bounds and limitations of the approved operating envelope and Safety Case authorization basis? ☒ Yes ☐ No

If "Yes" list the Operating Envelope/Safety Cases Document and Version Number:

Operating Envelope/Safety Case # 1132-Integration Laboratory (Issue # Rev 1, 9/17/2014)

Go to Part II: Work Approval.

If "No" enter what needs to be done to accept this work:

Accept, Reject or Continue Work:

Work is: ☒ Accepted ☐ Rejected

If rejected, state reason:

Line Manager Approval: [signature] Date: 9/18/2014

PART II: WORK APPROVAL

Describe briefly what was done to update the Operating Envelope / Safety Case Documents and approach to perform this activity level work.(if activity level work is covered under existing Operating Envelope/Safety Case, just note this here).

The activity level work represented in this AAA form is covered under an existing Operating Envelope/Safety Case.

Technical Work Documents (TWD):

List the Operating Envelope/Safety Case documents that have been updated or previously approved for performing this activity-level-work.

Number	Title	Approved On:
SOP 1100.001	Working with Hazardous and Particularly Hazardous Chemicals in SNL/NM Center 1100	1/7/2013
OP1100.207	Integration Laboratory General Procedure	

Line Manager having approval authority for Operating Envelope/Safety Case and associated TWDs.

Signature: [signature] Date: 9/17/2014

PART III: WORK AUTHORIZATION

Confirm Readiness

Line manager walk-down:	☒	Final walk down performed on 9/17/2014
Confirm team training qualifications:	☒	Training confirmed on 9/17/2014
Conduct readiness reviews or assessments:	☒	Readiness Review and Assessments on 9/17/2014

Decision to Authorize Work

Work is: ☒ Authorized ☐ Authorized but with limitations ☐ Not Authorized

Describe/Document limiting conditions to be placed on this authorization:

Line manager having approval authority to authorized work:

Signature: [signature] Date: 9/17/2014

OE# 1132-IL
Issue # REV 1
Date: 9/17/2014

Operating Envelope for SNL/NM Center 1100

Laboratory: Building 518/ Room Integration Lab

Part A: Laboratory Overview and Background information

PHS Identification

PHS-SNL06A00448-010 CINT Integration Lab

PHS-SNL06A00922-008 CINT Rms: 1522 & 1523 - Lithography Bay and Chase; PHS-SNL06A00448-008 CINT (clean room, all labs) - Integration Lab

PHS-SNL07A00125-008 CINT Rms: 1524, 1525 & 1526 - Metal Deposition Lab; PHS-SNL06A00448-008 CINT (clean room, all labs) - Integration Lab

PHS-SNL10A00226-004 CINT Rms: 1532 and 1533-Flex Bay, Diffusion Area

NEPA SNA07-0202 - CINT Integration Laboratories (1501, 1504, 1523, 1525, and 1527)
NEPA SNA10-0201- CINT Building 518/1532 Installation and Operation of Low Pressure Chemical Vapor Deposition Furnace

Laboratory Owner

John Nogan, 1132, 284-8863

Work Planning Team

	Organization	Position	Phone	Email
John Nogan	1132	CINT Scientist (SMTS)	284-8863	jnogan@sandia.gov
Anthony James	1132	CINT Technologist (PTNG)	284-9157	arjames@sandia.gov
Denis Webb	1132`	CINT Technologist (PTNG)	845-0509	dbwebb@sandia.gov
Jeffrey Nelson	1131	CINT Manager	284-1715	jsnelso@sandia.gov

Date of Laboratory Walkthrough: 8/8/2014

Brief Description of R&D Work Performed:

Rooms 1522/1523/1524:
Room 1522 and 1523 are designated the lithography room and chase, respectively. Chase 1522's function is to provide space for the return air from lithography room 1523, and to house the gas lines, electrical outlets, vacuum pumps, and exhaust handling system. No laboratory experiments will be performed in this area. However, the area will be used for routine maintenance of the equipment in 1523 and to provide storage for lab user PPE (Personal Protective Equipment). Room 1523 will be used for the process and associated metrology of contact mask lithography. This includes processing of industry standard photoresist, which typically requires spinning the photoresist on a wafer followed by exposing using a UV (260nm/365nm) contact mask aligner and baking up to 400C on a hot plate or up to 250C in an oven. The photoresist is then typically developed using a base such as KOH (Potassium Hydroxide) or TMAH (Teramethylammonium Hydroxide) and can be removed using a common solvent. An O2 (oxygen) plasma or atmospheric O3 (ozone) surface clean typically follows the develop step to remove residual photoresist. Metrology equipment used in this process includes an optical microscope for visual inspection.

Room 1525 /1526: Room 1525 and chase 1526 bay contains multiple vacuum deposition systems (base pressure 10^-7 torr) for the deposition of high purity materials typically used in lift-off and subtractive etching processes. Additionally, the sputter deposition tools can be configured for conformal deposition of many types of metals, dielectrics and ternary compounds.

The chemical benches will be used for standard processing of devices fabricated on a variety of substrate materials which include silicon, quartz, and a range of III-V compound semiconductors. Typical processes will include removal of photoresist and degreasing using solvents, wet chemical etching of metals, Si, and SiO2 and other standard processes. The rapid thermal annealer (RTA) uses a set of bulbs to rapidly heat silicon wafers to temperatures in excess of 1000C in an inert environment, such as N2. Additionally, forming gas (3.8% H2/ balance nitrogen) can be used to prevent oxide formation during annealing.

Room 1532 /1533: Chemical Vapor Deposition (CVD) is a chemical process used to deposit high-quality thin film dielectric materials onto a variety of surfaces. The process is often used for microelectronic and MEMS (Micro Electrical Mechanical System)/NEMS (Nano Electrical Mechanical Systems) fabrication. In a typical CVD process, the wafer (substrate) is exposed to one or more volatile precursors, which react and/or decompose on the substrate surface to produce the desired thin film material. Low pressure CVD (LPCVD) is a process that is performed at a sub atmospheric pressure typical less than 1Torr. Reduced pressure tends to reduce unwanted gas-phase reactions and improve uniformity across the wafer. Thermal Oxidation is an atmospheric pressure process where a silicon substrate is exposed to an oxygen enriched environment at high temperature for the purpose of growing a high quality silicon dioxide thin film. This dielectric is commonly used for the fabrication of a variety of microelectronic and MEMS/NEMS type devices. The oxidation process can be accelerated by introducing steam into the oxidation chamber. Oxidation processed typically run for several hours however thicker films in the order of several microns can take several days or even weeks.

Room 1527 has two inductively coupled plasma (ICP) etch systems, a plasma enhanced chemical vapor deposition (PECVD) system, an electron beam/thermal evaporator, and an atomic layer deposition (ALD) system. **Room 1530** has a silicon deep reactive ion etcher (SiDRIE), a parallel plate reactive ion etch reactor, a downstream low frequency plasma reactor, a probe station with miscellaneous metrology equipment and a confocal microscope. The PECVD system allows for the conformal deposition of multiple types of dielectric and other materials, such as poly-Si, silicon nitride, and silicon oxides. The ICP etch systems are used for dry etching aluminum, organic materials, oxides, nitrides, polysilicon, among other materials. Each of the etch tools in **Room 1527** have class 2 lasers for endpoint detection. The ALD system is used for conformal deposition of dielectric and metallic films with single atomic layer control on 3-dimensional nanostructures with aspect ratios of more than 2000. Standard ALD thin films include hafnium oxide, aluminum oxide, titanium nitride, zirconium oxide, and platinum. Ammonia and oxygen process gasses are also supplied to the ALD apparatus. With exception to argon purge cylinders and octofluorocyclobutane for etch processing, all non-toxic gasses are distributed to the tools in **Rooms 1527 and 1530**. The toxic etch gasses which include chlorine, boron trichloride and ammonia are self-contained within built-in toxic gas cabinets in each tool in Room 1527. A fully automatic silane gas cabinet for the CVD reactor (**Room 1527**) and LPCVD furnace (**Room 1532**) is also located in chase **Room 1528**. There are toxic-gas monitoring sensors located in each of the gas cabinets and in the vicinity of the tools to detect leaks.

Hazard Identification

Unacceptable Outcomes:

1. No individual will suffer like-altering injuries while conduction an experiment.
2. No individual or the public will be unnecessarily exposed to chemicals.
3. No individual will come in contact with energized electrical circuits greater than 50 volts AC or 100 volts DC
4. Laboratory equipment shall not be damaged
5. Failure that would stop operations at the facility for more than one month.
6. Facility outages of more than 10 weeks.

Common Hazards (Hazards Covered by Common Center-Level Safety Cases)

Chemical Environmental Mechanical Thermal Non-ionizing Radiation

Specific Hazards (Hazards Covered by a Safety Class)

1. Safety Case #1 – Wet Chemistry Processing Area
2. Safety Case #2 – Plasma Etch Processing Area
3. Safety Case #3 – Chemical Vapor Deposition (CVD) and Physical Vapor Deposition (PVD) Processing Area
4. Safety Case #4 – Thermal Processing Area
5. Safety Case #5 – Photo Lithography Processing Area
6. Safety Case #6 – Metrology Area (General Use Equipment)

Laboratory Technical Work Documents
1. SOP1100.001: Standard Operating Procedures for working with hazardous and particularly hazardous chemicals in SNL/NM Center 1100 Laboratories.
2.OP1100.207 Integration Lab General Operating Procedure

Part B: Operations Identification, Hazards, and Mitigation

Common Laboratory Hazard Category: Chemical Usage

Description of Chemical Usage Hazards:

Acids: Hydrofluoric, hydrochloric, sulfuric, acetic, nitric and orthophosphoric
Bases: Tetramethylammonium hydroxide, potassium hydroxide, ammonium hydroxide and ammonium sulfide.
Oxidizers: Hydrogen Peroxide, O3 (Ozone)
Solvents: Small amounts of organic solvents such as isopropanol, methanol, ethanol, acetone, positive and negative photoresist, PGMEA (propylene glycol monomethyl ether acetate), toluene, and NMP (N-methylpyrrolidone) are commonly used.

Various developers are also used in laboratory operations. Bases are used to develop the photoresist after exposure on the mask aligner. The base bench is a locally ventilated hood; the potential for exposure to chemical vapors is low based on the small quantities used and the use of local exhaust ventilation. The solvent bench is a locally ventilated hood with a solvent collection system. Air discharges are small and consistent with typical R&D operations. The potential for exposure to solvent vapors is low based on the small quantities used and the use of local exhaust ventilation. The UV Ozone cleaning system generates a quantity of low level ozone through the exposure of room air to ultraviolet light in a controlled chamber. Risk of exposure to ozone is mitigated through the use of interlocks and local exhaust ventilation. Handling of Acid/Base process chemistries that exhibit a particularly above average risk are clearly outlined in “Chemical Processing Guides”. These Chemical Processing Guides can be found in the Acid/Base Wet Bench Tool Specific Notebook. DCS, Silane and Ammonia are stored and delivered from ventilated, fully automatic gas cabinets. Toxic gas monitoring senor and fire detectors are also incorporated into the gas cabinets, furnace source cabinet and chase to detect the presents of an uncontained gas leak. If a leak or fire is detected, the tool is placed into a fail-safe condition and the toxic gasses are shut off at the bottle. TEOS is stored in a ventilated enclosure within the tool. The TEOS is not monitored by the tool of facility’s TGMS.

Baseline Occupational Exposure Assessments were completed and are listed below:
ER2007-2646 - Baseline OEA (518/1522/1523) CINT Rm: 1522 & 1523 - Lithography Bay and Chase

Baseline Occupational Exposure Assessments were completed and are listed below:
ER2007-2630 - Baseline OEA (518/1525) CINT Rm: 1525 – Metal Deposition Lab

Exposure Assessment Survey Report SNLNM02759
Toxic Gas: Disilane (Dichlorosilane or DCS), 100% Silane, and Ammonia

Conclusions stated that exposure controls are adequate for laboratory operations.

Applicable Technical Work Documents:	Required Training:
• SOP1100.001 Standard Operating Procedure for Working with Hazardous and Particularly Hazardous Chemicals in SNL/NM Center 1100 Laboratories	• ESH100 ES&H Awareness • CHM100 Chemical Safety Training • CHM103 Site-Specific Chemical Safety Training • ENV112 Hazardous Waste and Environmental Management • ILUA Integrated Lab Unescorted Assess Training
These documents are required reading for all authorized workers.	**These courses are required training for all authorized workers.**

Possible Chemical Hazards:	**Mitigation of Chemical Hazards:**
• Adverse reaction from contact with incompatible materials. • Fire due to exposure to an ignition source. • Bodily Injury due to absorption, injection, ingestion or inhalation of a toxic substance. • Refer to the Material Safety Datasheets for more detailed information on material specific hazards. • Inhalation during servicing or cylinder exchange.	Solvents are stored in an approved flammable cabinet. Other hazardous liquids are stored in the appropriate manner per SOP1100.001. A minimum of latex gloves and safety glasses are worn while handling hazardous liquids to mitigate incidental contact and are handled in the fume hood. Calcium gluconate is available in the event of a dermal exposure to hydrofluoric acid. To mitigate incidental contact, all chemicals are handled with basic PPE (latex gloves and safety glasses) and always in a fume hood. Additional PPE (specific chemical resistant gloves, lab coat and safety goggles) is utilized based on the chemical hazard as per the chemical MSDS and SOP1100.001. All hazardous waste is disposed of in accordance with SOP1100.001. Engineering controls to include fully automatic gas cabinet which allows operator to maintain control of gases outside of the hazardous area. Air purifying respirator

Common Laboratory Hazard Category: Environmental

Description of Environmental Hazards:

Solid as well as liquid hazardous waste is generated during operation processes.

Effluent from Tubes 2, 3 and 4 are directed through a two-stage dynamic oxidation and water scrub abatement system. Tube 2 is processed through both stages to react/collect solids and then neutralize the DCS and NH_3. Tube 3 is processed through the dynamic oxidation stage to react the Silane with air in order to form SiO_2. The SiO_2 is then trapped in a particulate filter. Tube 4 is only processed through the dynamic oxidation stage to collect any particulate; the byproduct of TEOS is ethanol.

Applicable Technical Work Documents:	**Required Training:**
• SOP1100.001 Standard Operating Procedure for Working with Hazardous and Particularly Hazardous Chemicals in SNL/NM Center 1100 Laboratories **These documents are required reading for all authorized workers.**	• CHM100 Chemical Safety Training • CHM103 Site-Specific Chemical Safety Training • ENV112 Hazardous Waste and Environmental Management. • ILUA Integrated Lab Unescorted Assess Training **These courses are required training for all authorized workers.**
Resulting Hazards: • Adverse reaction from contact with incompatible materials. • Fire due to exposure to an ignition source. • Bodily Injury due to absorption, injection, ingestion or inhalation of a toxic substance. • Environmental concerns if organic solvent should	**Mitigation of Identified Hazards:** Solvent contaminated wipes, swabs, and gloves will be disposed of in the trash receptacles marked Solvent. Dried wipes of evaporated acetone, isopropanol, or methanol may be disposed of in the non-hazardous trash.

enter the wastewater treatment system. • Solid solvent waste placed in landfill could leak and enter the environment. • Refer to the Material Safety Datasheets for more detailed information on material specific hazards.	

Common Laboratory Hazard Category: Mechanical hazards	
Description of Mechanical Hazards: Portable power tools, 0-10,000 rpm resist spinners	
Applicable Technical Work Documents: • N/A **These documents are required reading for all authorized workers.**	**Required Training:** • ESH100 ES&H Awareness • ILUA Integrated Lab Unescorted Assess Training **These courses are required training for all authorized workers.**
Resulting Hazards: • Bodily injury which could include, sprains, cuts and scrapes. • Eye Injury possible if ANSI approved safety glasses are not worn during this activity. • Electrical injuries	**Mitigation of Identified Hazards:** On-the-Job training is conducted if necessary by personnel.

Common Laboratory Hazard Category: Thermal hazards	
Description of Thermal Hazards: Hot plates are used as part of operations in this area. .	
Applicable Technical Work Documents: • N/A **These documents are required reading for all authorized workers.**	**Required Training:** • ESH100 ES&H Awareness • ILUA Integrated Lab Unescorted Assess Training **These courses are required training for all authorized workers.**
Resulting Hazards: • Prolonged contact with hot plate surfaces at elevated temperature could result in severe burns.	**Mitigation of Identified Hazards:** Lab personnel read the manufacturer's manual prior to use and have on the job training prior to use of this equipment.

<table>
<tr><td colspan="2">Common Laboratory Hazard Category: Non-ionizing radiation</td></tr>
<tr><td colspan="2">Description of Non-ionizing radiation:
After the photoresist is applied and baked, the wafers are exposed in the UV mask aligner (deep-UV 265 and near-UV365-400 nm, up to 500 watts).</td></tr>
<tr><td>Applicable Technical Work Documents:
• Equipment manuals.

These documents are required reading for all authorized workers.</td><td>Required Training:
• On-the-job training is given to those utilizing the UV lamps prior to use.
• ILUA Integrated Lab Unescorted Assess Training

These courses are required training for all authorized workers.</td></tr>
<tr><td>Resulting Hazards:
• UV exposure from contact aligner lamp modules.</td><td>Mitigation of Identified Hazards:
• The UV Mask Aligner is shielded to prevent exposure to UV light.
• The potential for exposure to hazardous levels of UV light is low.</td></tr>
</table>

Integration Laboratory Processing Building 518

Safety Cases:
Safety case development meeting and laboratory assessments were held for the CINT Processing areas on 8/8/2014. Six safety cases were developed:

- Safety Case #1 - Wet Chemistry Processing Area
- Safety Case #2 - Plasma Etch Processing Area
- Safety Case #3 - Chemical Vapor Deposition (CVD) and Physical Vapor Deposition (PVD) Processing Area
- Safety Case #4 - Thermal Processing Area
- Safety Case #5 - Photo Lithography Processing Area
- Safety Case #6 - Metrology Area (General Use Equipment)

LOCATIONS				
Site	**Area**	**Building**	**Room**	**Description**
SNLNM	CINT	518	1523, 1524,1525	Wet Chemistry Processing Area
SNLNM	CINT	518	1527, 1528, 1530	Plasma Etch Processing Area
SNLNM	CINT	518	1525,1526, 1527, 1528	Chemical Vapor Deposition (CVD) and Physical Vapor Deposition (PVD) Processing Area
SNLNM	CINT	518	1525, 1532, 1533	Thermal Processing Area
SNLNM	CINT	518	1523, 1524	Photo Lithography Area
SNLNM	CINT	518	1523,1527,1530, 1532	Metrology Area (General Use Equipment)

Who is the Decision maker for All Six Safety Cases Listed Below?
Standard Industrial Low/Neal Shinn, Acting Manager Department 1132

Safety Case #1:
Wet Chemistry Processing Area:

How is the system defined?
Wet Chemical Processing Area is set up to provide users the following:
- Pour up and mix chemicals into beakers in a ventilated and chemically compatible Wet Bench
- Chemically etch/clean wafers/pieces using room temperature and temperature controlled hot plates
- Safely dispose of all hazardous waste.
- The meeting involved a discussion of the hazards 3 key areas:
    1. Dispensing of chemicals.
    2. Performing an experiment using chemicals.
    3. Disposal of chemicals.

What are the unacceptable consequences?

- Severe injury from contact or inhalation of hazardous chemicals and materials, either acute or chronic exposure.
- Severe personnel exposure to hazardous chemicals via: Absorption, Inhalation, Injection or Ingestion.
- Incidental contact to residual chemicals when an Integration Laboratory Worker (ILW):
    1. Does not properly dispense photoresist or polymers in the approved photoresist spinner bench.
    2. Fails to properly rinse dishware after use, or flush an empty chemical bottle three times before positioning the bottle to be disposed or recycled.
    3. Fails to remove contaminated PPE while inspecting samples at a microscope, using the telephone, or touching door handles.
    4. Continues to use PPE that is damaged or has been used beyond its appropriate service life.
- Incidental contact to chemicals when a member of the
- Pinch points
- Thermal contact
- Electrical hazards
- Lifting hazards
- Fire hazards
- Inhalation of hazardous media
- Destruction or damage to tools causing impact to CINT operations that result in the delay of experiment execution and data collection.
- Environmental harm from hazardous effluent being released into the waste water stream.
- Environmental harm related to the uncontrolled wastewater release above outside of permitted parameters for pH, arsenic or other regulated materials from acid waste neutralization (AWN) to city sanitary sewer system.

How can the system fail?

- Operator error from not understanding or following documented operating procedures (OP)
- Exposure to liquid or vapor during the dispensing of the chemical could result in serious injury by:
    1. Not verifying bench is operational
    2. Spills during chemical pouring
    3. Leaking bottle or contaminated exterior surface of chemical container
    4. Improperly labeled chemical containers
    5. Incorrect personal protective equipment (PPE) or contaminated PPE
    6. Incorrect wet bench/drain or mixing incompatible chemicals in processing containers
    7. Insufficient or obstructed exhaust flow
    8. Inadequate procedures and training

- Loss of control of the process chemistry during the experiment can be caused by:
    1. Holes, cracks, or leaky laboratory dishware.
    2. Exceeding the operating parameters of the equipment associated with the experiment.
    3. Not reading or understanding the limitations of the chemicals or incompatibilities
    4. Material fatigue or incompatible material
    5. Human error - improper settings or incorrect assembly.
    6. Human error – improper or insufficient planning of experiment
    7. Underestimating the hazards associated with common chemistries.
    8. Failure to read a materials SDS (Safety Data Sheet) prior to mixing chemicals.

- Failure of uncontrolled wastewater release can be caused by:
    1. Human error – introducing chemicals into incorrect the waste stream
    2. Accidental damage to laboratory dishware.
    3. Material fatigue or incompatible material
    4. Incorrect wet bench/drain or mixing incompatible chemicals in processing containers

What are the controls and how do you verify the controls are working?

- Wet chemical equipment installed in the CINT IL is designed for proper exhausting of chemical vapors.
- The exhaust levels are determined through testing and by following published guidelines.
- The exhaust balancing and annual check are performed by Kirk Air, Incorporated and follow Sandia's LEV protocol.
- Preventive maintenance schedules for each tool include a periodic check of the exhaust and verification
  of operating parameters.
- The Wet Bench tools will alarm if exhaust is below a safe level or is inadvertently lost.
- A pressure gauge located on the exhaust connection to each Wet Bench provides a visual check for the presents of exhaust flow.
- Solvent bench hot plates and carboy level detectors are designed to prevent accidental ignition of hazardous vapor.
- All wet bench electrical enclosures are purged with nitrogen to prevent hazardous vapors from entering and to slow or stop flame propagation in the event of fire.
- All wet benches are equipped with ground fault interrupter outlets to prevent accidental electrocution.
- All wet bench power distribution schemes follow NEC guidelines to prevent fire due to component failure or circuit overload.
- Periodic exposure assessments performed by Sandia Corporate Industrial Hygiene group.
- Authorized use of a wet chemical processing tool in the CINT IL is administratively controlled through Training
- A user must be signed off by the Key Operator prior operating the equipment.
- Documented controlled training task lists developed by the Key Operator guide the trainer and trainee.
- Training on the proper use of PPE and equipment operating procedures is required prior to authorization of use for the equipment.
- Placard signs are located on each tool that designates the equipment status - Up (green) and Down (red).
- Lock-Out-Tag-Out (LOTO) procedures are adhered to when performing equipment maintenance activities.
- Each Acid/Base wet bench has sensors installed that can detect chemical leaks below the sink or within the chemical storage areas of the tool.
- All tools have emergency power off (EMO) and software interlocks that prevent operation if the system fails.
- All tools have a pressure safety data package that has been reviewed and approved by the subject matter expert.
- The arsenic drain is connected to specific tools that generate effluent materials containing arsenic particulate.
- The arsenic drain routes to a separate collection system that removes arsenic containing material before entering the acid waste stream.
- All effluent chemical waste is continuously monitored for pH, and periodically sampled for fluoride, arsenic, and other NMED regulated constituents.
- Daily "pad" checks are performed by IL Staff ensure that the Acid Waste Neutralization (AWN) system is working properly.
- Abnormal conditions in the AWN are immediately reported to EOC through the facilities management system to the building operator, and to IL Staff who performs daily operational checks, calibrations, etc., and are on-call 24/7 to respond to address issues.
- In summary, the engineering, administrative and PPE controls within the wet chemical processing area work well. Periodic review of these controls and continuous improvement methodologies are also implemented as needed.
- Engineering Controls in the IL Processing areas include tool safety interlocks that are incorporated into the

tool operating software.

Line Decision on Approval of the Safety Case (completed by management)

(Jeffrey Nelson, Manager-1131, for Neal Shinn, 1130, acting 1132) I was part of the work planning team and participated on the development of the safety case for this laboratory. I am comfortable with the level of critical thinking involved in the safety and hazard analysis of this laboratory. I also concur with the implementation of new Engineered Safety Controls (administrative and engineered) that have been implemented as a result of this Work Planning &Controls-Engineered Safety activity.

Jeffrey P. Nelson 9/17/2014

Safety Case #2: Plasma Etch Processing Area:

How is the system defined?

The Plasma Etch area is set up to provide users the following:

- Equipment to perform plasma etching on wafers/pieces,
- Equipment to perform plasma ash photo resist removal on wafers/pieces.

What are the unacceptable consequences?

- Severe injury from inhalation of hazardous gases and byproducts, either acute or chronic exposure.
- Direct and indirect unshielded contact with live radio frequency energy, causing severe harm.
- Destruction or damage to tools causing impact to CINT operations that result in the delay of processing sequence scheduling.

How can the system fail?

- The following are hazardous gases used in the Dry Etch area:
  1. Chlorine (Cl_2),
  2. Boron Trichloride (BCl_3),
- Exposure to hazardous particulate can occur when:
  1. Proper PPE is used while performing major chamber maintenance that could generate large volumes of particulate.
  2. HEPA/ULPA filtered vacuum cleaners for chamber "spot" cleaning are not properly maintained.
  3. Metal deposition chambers are not periodically cleaned or properly maintained.
- Exposure to hazardous substances can occur when:
  1. An Integration Laboratory Worker (ILW) defeats the tool safety interlocks and does not follow proper Lock-Out-Tag-Out (LOTO) procedures.
  2. Outgassing of Chlorine and the formation of Hydrogen Chloride during chamber cleaning maintenance activities.
  3. Outgassing of toxic vapors during pump maintenance.
  4. Proper personnel protective equipment (PPE) is not worn during cylinder exchange or when servicing specific areas of tool.
  5. The local exhaust fails.
- Exposure to radio frequency (RF) power can occur when:
  1. LOTO procedures are not followed during maintenance activities
  2. Tool safety interlocks are defeated.

3. Shields are removed.
4. RF transmission line severed or damaged.
5. Loose or open RF transmission line connection.

- Destruction or damage to tools causing impact to CINT Operations and delay of mission deliverables can
occur when:
  1. Poorly designed tool parameters or the tool is operated outside of designed use.
  2. Not following guidelines established by tool owner.
  3. Cooling water leak spilling into electronic enclosures.
  4. Poorly designed equipment with inadequate interlocking or electrical systems that do not follow common design practices or NEC guidelines.

<u>What are the controls and how do you verify the controls are working?</u>

Engineered Controls

- Engineering Controls in the Dry Etch area include tool safety interlocks that are incorporated into the tool operating software. The tool operating software will also drive gas delivery valves into a closed position in the event of system failure.
- All corrosive and toxic gasses are integrated into the tool's ventilated gas box.
- Quantities of toxic gasses on site are maintained below de minimis levels.
- Extensive hazardous gas monitoring is performed continuously in the gas distribution system (gas cabinets, chases, processing area) for each tool. In the event of a toxic gas alarm, the monitoring system automatically triggers gas shut-down of the specific hazard at the source and the process aborts. If the leak is contained within the gas box, in addition to the source shutdown a local alarm is activated which does not prompt an evacuation. If the leak is detected by the ambient sensors, a 518 building wide evacuation alarm is triggered and an emergency response from the Kirtland Air Force Base Fire Department is initiated.
- Details of the safety controls for hazardous gases are outlined in several documents which include, but are not limited to Bldg. 518, Integration Lab PHS, Integration Lab General Operating Procedure and Toxic Gas Monitoring System Procedure, OP for Toxic/Pyrophoric/Inert Gas Cylinder Change-Out in Building 518.

Administrative Controls and Personal Protective Equipment (PPE)

- Administrative procedures include written operation and maintenance procedures for each dry etch tool, must be adhered to during operation or maintenance (including gas bottle exchanges).
- An operator or maintenance person must be signed off by the Key Operator prior using or performing corrective maintenance on the equipment.
- Documented, training task lists, quick reference guides developed by the Key Operator guide the trainer and trainee.
- Training on the proper use of PPE and equipment operating procedures is required prior to authorization of use for the equipment.
- Lock-Out-Tag-Out (LOTO) procedures are adhered to when performing equipment maintenance activities.
- All tools have been designed to meet the Sandia electrical safety standards and have been reviewed through the NRTL compliance program.
- All system interlock switches (vacuum, atmospheric, and proximity) are checked and verified during corrective maintenance activities.
- Work documents are periodically reviewed and the LOTO procedures are developed and inspected on a periodic basis.
- HEPA/ULPA vacuums are tested and tagged for compliance by a third party on an annual basis to detect component failure, leaking filters or seals. Vacuums are serviced in a ventilated hood with appropriate respiratory protection.
- Some examples of tools causing impact to CINT Operation and delay of mission deliverables include:

1. The Plasma-Therm Silicon Deep Reactive Ion etch tool could have a catastrophic failure in the ICP (Inductively Coupled Plasma) antenna, RF match or Generator due to improper operation or operating the system beyond design limits. This may cause significant down time and impact to various user processing schedules.
2. The Trion Chlorine or Fluorine etch tool, the Plasma-Therm SiDRIE may experience turbo molecular pump failure due to loss of balance during operation caused by a high foreline pressure or an abrupt mechanical shock to the pump housing or reactor mainframe. This may result in extended equipment downtime at a high cost.
3. The Trion etch tools have poorly developed, proprietary control systems and software, and lack the most basic information such as schematics for troubleshooting and spare parts identification for ordering replacement parts. Troubleshoot of system electrical problems often requires extensive point to point tracing of electrical circuits. Mechanical failures require reverse engineering and the remanufacture of parts to return the system to service. This results in extended down time or the initiation of workarounds to keep the system operational which both inhibit the ability to meet certain user deadlines.

Line Decision on Approval of the Safety Case (completed by management)

(Jeffrey Nelson, Manager-1131, for Neal Shinn, 1130, acting 1132) I was part of the work planning team and participated on the development of the safety case for this laboratory. I am comfortable with the level of critical thinking involved in the safety and hazard analysis of this laboratory. I also concur with the implementation of new Engineered Safety Controls (administrative and engineered) that have been implemented as a result of this Work Planning &Controls-Engineered Safety activity.

Jeffrey J. Nelson 9/17/2014

Safety Case #3:
Chemical Vapor Deposition (CVD) and Physical Vapor Deposition (PVD) Processing Area

How is the system defined?

The CVD and Metals areas are set up to provide users the following:

- Equipment to perform plasma-enhanced chemical vapor deposition (ICP CVD) on wafers/pieces
- Equipment to perform Radio Frequency (RF) and Direct Current (DC) magnetron sputter, Electron Beam (EBeam) and thermally evaporated film deposition on wafers/pieces.

What are the unacceptable consequences?

- Personnel injury from inhalation of hazardous gasses such as silane and ammonia.
- Personal injury from inhalation of particulate during chamber cleaning or more in depth maintenance procedures.
- Direct or incidental contact with high-voltage (up to -10keV potential) electricity.
- Exposure to radio-frequency (RF) through direct contact with a source.
- Direct contact with hot surfaces
- Direct contact with cold surfaces (Cryogenic hazards).
- Pinch hazards when lowering chamber lids, closing doors
- Lifting hazards while loading process fixtures.
- Falling off a step stool while exchanging source materials or replacing crystals.
- Accidental damage to tools causing impact to CINT operations that result in the delay of user processing
schedules.

- Environmental harm from hazardous gas release.
- Simple asphyxiation, entering a PVD vacuum chamber while purging with nitrogen.

How can the system fail?

- Exposure to hazardous gases can occur when:
  1. Lock-Out-Tag-Out (LOTO) procedures are not followed during maintenance activities.
  2. Chambers and gas system components are not properly purged or prepared for servicing.
  3. Tool safety interlocks are defeated.
- Exposure to hazardous particulate can occur when:
  1. Proper PPE is used while performing major chamber maintenance that could generate large volumes of particulate.
  2. HEPA/ULPA filtered vacuum cleaners for chamber "spot" cleaning are not properly maintained.
  3. Metal deposition chambers are not periodically cleaned or properly maintained.
- Exposure to RF power can occur when:
  1. LOTO procedures are not followed during maintenance activities.
  2. Tool safety interlocks are defeated.
  3. Faulty components or removal of shields.
- High voltage contact (up to -10keV potential)
  1. LOTO procedures are not followed during maintenance activities.
  2. Source power supply capacitors are not properly discharged or grounded during emitter source maintenance activities.
  3. Tool safety interlocks are defeated.
  4. Faulty components or removal of safety shields.
  5. Improperly rated equipment used for high voltage measurement.
  6. Inadequate or poor emitter to power supply grounding, or system grounding.
- Exposure to hot surfaces can occur when:
  1. LOTO procedures are not followed during maintenance activities.
  2. Tool safety interlocks are defeated.
  3. Maintenance workers fail to properly cool certain CVD chamber components before servicing, or fail to cool thermal boats before removal or replacement of quartz cover, or tungsten boat.
- Exposure to Cryogenic hazards can occur when:
  1. LOTO procedures are not followed during maintenance activities on Ebeam or Thermal evaporation deposition equipment.
- Exposure to pinch hazards can occur when:
  1. Chamber lift mechanism lead screws fail.
  2. When workers are not careful while closing a chamber lid.
- Exposure to lifting hazards can occur when:
  1. Proper lifting procedures are not followed during certain maintenance activities.
- Falling from a stool or ladder while loading system:
  1. Care is not taken to correctly position step stool or ladder before stepping.
  2. Climbing too high or losing balance due to overreaching and not repositioning the stool/ladder.
- Environmental harm from hazardous gas release can occur when:
  1. LOTO procedures are not followed during maintenance activities.
  2. Tool safety interlocks are defeated.
  3. The Toxic Gas Monitoring System (TGMS) is bypassed.

What are the controls and how do you verify the controls are working?

Engineered Controls

- Engineered Controls in the CVD and PVD areas include tool safety interlocks that are incorporated into the tool operating software. The tool operating software will also drive gas delivery valves into a closed position in the event of system failure.

- Quantities of toxic gasses on site are maintained below de minimis levels.
- Extensive hazardous gas monitoring is performed continuously in the gas distribution system (gas cabinets, chases, processing area) for each tool. In the event of a toxic gas alarm, the monitoring system automatically triggers gas shut-down of the specific hazard at the source and the process aborts. If the leak is contained within the gas box, in addition to the source shutdown a local alarm is activated which does not prompt an evacuation. If the leak is detected by the ambient sensors, a 518 building wide evacuation alarm is triggered and an emergency response from the Kirtland Air Force Base Fire Department is initiated.
- Details of the safety controls for hazardous gases are outlined in several documents which include, but are not limited to Bldg. 518, Integration Lab PHS, Integration Lab General Operating Procedure and Toxic Gas Monitoring System Procedure, OP for Toxic/Pyrophoric/Inert Gas Cylinder Change-Out in Building 518.

Administrative Controls:

- Administrative procedures include written, revision-controlled operating procedures for each deposition tool that
  must be adhered to during operation or maintenance (including gas bottle changes).
- An operator or maintenance person must be signed off by the Key Operator prior to using or repairing the equipment.
- Documented and revision-controlled training task lists developed by the Key Operator guide the trainer and trainee.
- LOTO, electrical safety procedures are adhered to when performing equipment maintenance activities.
- Documented, training task lists, quick reference guides developed by the Key Operator guide the trainer and trainee.
- Training on the proper use of PPE and equipment operating procedures is required prior to authorization of use for the equipment.
- Lock-Out-Tag-Out (LOTO) procedures are adhered to when performing equipment maintenance
- activities.
- All tools have been designed to meet the Sandia electrical safety standards and have been reviewed through the NRTL compliance program.
- All system interlock switches (vacuum, atmospheric, and proximity) are checked and verified during corrective maintenance activities.
- Work documents are periodically reviewed and the LOTO procedures are developed and inspected on a periodic basis.
- HEPA/ULPA vacuums are tested and tagged for compliance by a third party on an annual basis to detect component failure, leaking filters or seals. Vacuums are serviced in a ventilated hood with appropriate respiratory protection.

Personal Protective Equipment (PPE):

- Proper PPE is worn during all maintenance and operating activities with the degree of PPE specified appropriate to the hazard level of the given activity.
- The PPE for each activity is documented through operating procedures (OP) and or Industrial Hygiene Exposure Assessments.

Line Decision on Approval of the Safety Case (completed by management)

(Jeffrey Nelson, Manager-1131, for Neal Shinn, 1130, acting 1132) I was part of the work planning team and participated on the development of the safety case for this laboratory. I am comfortable with the level of critical thinking involved in the safety and hazard analysis of this laboratory. I also concur with the implementation of new Engineered Safety Controls (administrative and engineered) that have been implemented as a result of this Work Planning &Controls-Engineered Safety activity.

Jeff Nelson, 9/17/2014

Safety Case #4: Thermal Processing Area

How is the system defined?
The Thermal Processing Area toolset consists of the following:

- One furnace with atmospheric processing tube for thermal oxide growth and anneal, and three Low Pressure Chemical Vapor Deposition (LPCVD) tubes for the deposition of polysilicon, silicon nitride and silicon dioxide thin films.
- One rapid thermal annealing system.
- One Thermal and Plasma Assisted Atomic Layer Deposition (ALD/PA-ALD) reactor.
- One Critical Point Dryer

What are the unacceptable consequences?

- Personnel injury from inhalation of hazardous gasses:
    1. Dichlorosilane (DCS),
    2. Silane,
    3. Ammonia,
    4. Tetraethylorthosilicate (TEOS)
- Exposure to hazardous particulate can occur when:
    1. Proper PPE is used while performing major chamber maintenance that could generate large volumes of particulate.
    2. HEPA/ULPA filtered vacuum cleaners for chamber “spot” cleaning are not properly maintained.
    3. Metal deposition chambers are not periodically cleaned or properly maintained.
- Contact with high-voltage
- Contact with high-current electricity,
- Direct contact with dangerously hot surfaces thermal oxidation to 1200°C, LPCVD to 1000°C, ALD to 600°C.
- Contact with and/or inhalation of toxic chemicals:
    1. Sub atmospheric Vapor Pressure, pyrophoric ALD organometallic precursors (TMA - Trimethylaluminum, TDMAH – Tektrakisdimethylamido Hafnium, Pt(EtCp)Me3 - (Trimethyl)Methycyclopentadienyl Platinum (IV) , BDEAS - Bis(diethylamino) Silane, etc.)
    2. Corrosive/Toxic ALD metal-halide ALD precursors ($TiCl_4$ – Titanium Tetrachloride, etc)
- Damage to tools causing impact to CINT operations that result in the delay of experiment execution and data collection scheduling.
- Environmental harm from hazardous gas or chemical release.

How can the system fail?

- Exposure to hazardous gases can occur when:
    1. Lock-Out-Tag-Out (LOTO) procedures are not followed during maintenance activities
    2. Tool safety interlocks are defeated.
- Exposure to high-voltage electricity:
    1. LOTO procedures are not followed during certain equipment repair activities.
    2. Removal of shields or improper shield installation.
- Exposure to hot surfaces can occur when:
    1. LOTO procedures are not followed during maintenance activities and tool safety interlocks are defeated.
    2. Workers are careless in loading and unloading furnace, rapid thermal anneal or ALD tools.

3. Losing control of quartz boat or underestimating the temperature level of certain components while loading or unloading the furnace

- Exposure to hazardous chemicals can occur when:
  1. LOTO procedures are not followed during maintenance activities and tool safety interlocks are defeated 2. Workers are careless in pouring up baths, and/or do not wear specified personal protection equipment (PPE) while operating the tools.
- Accidental damage to tools causing impact to CINT Operations and delay of mission deliverables can occur when:
  1. Extended downtime may be experienced if the wrong materials are loaded into the thermal oxidation or LPCVD processing tubes.
  2. Failure to follow the correct sequence while transferring material into the ALD reaction chamber.
  3. Dropping the RTA's graphite susceptor.
  4. Accelerated depletion of ALD precursor due to improper recipe adjustment.
- Environmental harm from hazardous gas release can occur when:
  1. LOTO procedures are not followed during maintenance activities
  2. Tool safety interlocks are defeated
- Environmental harm from chemical release can occur when:
  1. LOTO procedures are not followed during maintenance activities.
  2. Fume scrubber for LPCVD furnace is not properly monitored or maintained.
  3. Discharge incompatible chemicals down the acid waste neutralization (AWN) system.

What are the controls and how do you verify the controls are working?

Engineered Controls:

- Engineered Controls in the Thermal Processing Areas include tool safety interlocks that are incorporated into the tool operating software. The tool operating software for all furnaces and ovens will also drive gas delivery valves into a closed position in the event of system failure.
- All corrosive and toxic gasses are integrated into fully automatic gas cabinets with integrated fire detection and suppression systems.
- Quantities of toxic gasses on site are maintained below de minimis levels.
- Extensive hazardous gas monitoring is performed continuously in the gas distribution system (gas cabinets, chases, processing area) for each tool. In the event of a toxic gas alarm, the monitoring system automatically triggers gas shut-down of the specific hazard at the source and the process aborts. If the leak is contained within the gas box, in addition to the source shutdown a local alarm is activated which does not prompt an evacuation. If the leak is detected by the ambient sensors, a 518 building wide evacuation alarm is triggered and an emergency response from the Kirtland Air Force Base Fire Department is initiated.
- Details of the safety controls for hazardous gases are outlined in several documents which include, but are not limited to Bldg. 518, Integration Lab PHS, Integration Lab General Operating Procedure and Toxic Gas Monitoring System Procedure, OP for Toxic/Pyrophoric/Inert Gas Cylinder Change-Out in Building 518.

Administrative Controls:

- Administrative procedures include written, revision-controlled operating procedures for each deposition tool that
- must be adhered to during operation or maintenance (including gas bottle changes).
- An operator or maintenance person must be signed off by the Key Operator prior to using or repairing the equipment.
- Documented and revision-controlled training task lists developed by the Key Operator guide the trainer and trainee.
- LOTO, electrical safety procedures are adhered to when performing equipment maintenance activities.

- Documented, training task lists, quick reference guides developed by the Key Operator guide the trainer and trainee.
- Training on the proper use of PPE and equipment operating procedures is required prior to authorization of use for the equipment.
- Lock-Out-Tag-Out (LOTO) procedures are adhered to when performing equipment maintenance
- activities.
- All tools have been designed to meet the Sandia electrical safety standards and have been reviewed through the NRTL compliance program.
- All system interlock switches (vacuum, atmospheric, and proximity) are checked and verified during corrective maintenance activities.
- Work documents are periodically reviewed and the LOTO procedures are developed and inspected on a periodic basis.
- HEPA/ULPA vacuums are tested and tagged for compliance by a third party on an annual basis to detect component failure, leaking filters or seals. Vacuums are serviced in a ventilated hood with appropriate respiratory protection.

Personal Protective Equipment (PPE):

- Proper PPE is worn during all maintenance and operating activities with the degree of PPE specified appropriate to the hazard level of the given activity.
- The PPE for each activity is documented through operating procedures (OP) and or Industrial Hygiene Exposure Assessments.

Line Decision on Approval of the Safety Case (completed by management)

(Jeffrey Nelson, Manager-1131, for Neal Shinn, 1130, acting 1132) I was part of the work planning team and participated on the development of the safety case for this laboratory. I am comfortable with the level of critical thinking involved in the safety and hazard analysis of this laboratory. I also concur with the implementation of new Engineered Safety Controls (administrative and engineered) that have been implemented as a result of this Work Planning &Controls-Engineered Safety activity. Jeffrey J. Nelson 9/17/2014

Safety Case #5: Photo Lithography Processing Area

How is the system defined?

- The Photo Lithography area is set up to provide users the following:
    1. Equipment to process wafers/pieces with Photoresist and hexamethyldisilazane (HMDS)
    2. Resist spinners
    3. Bake tools (hot plates and ovens)
    4. Exposure tools (Contact aligners)
    5. Resist develop (manual)

What are the unacceptable consequences?

- Inhalation of Photoresist fumes from the storage refrigerator that may cause irritation.
- Exposure to large amounts of photoresist (gallon containers or more).
- Skin exposure to Tetramethylammonium hydroxide (TMAH) based resist developers.
- Destruction or damage to tools causing impact to CINT operations that result in the delay of experiment execution and data collection.
- Fire or hazardous exposure by creating non-standard waste streams from standard chemicals.

How can the system fail?

- Strong odors of photoresist fumes can build up in a refrigerator that house resist bottles that are routinely accessed for dispensing and use. The fumes can be smelled when the door to this refrigerator is opened.
- Carelessness, failure to follow best known practices and training while cleaving hazardous materials or transferring unbound nanomaterials to substrate surfaces outside of ventilated hoods.
- Exposure to photoresist and polymer fumes can occur when:
    1. An Integration Laboratory Worker (ILW) does not properly dispense photoresist in the approved photoresist spinner bench.
    2. An Integration Laboratory Worker (ILW) does not properly dispose of photoresist/polymers/thinners, propyleneglycolmethyletheracetate (PGMEA), chlorobenzene solid waste in the appropriately ventilated solvent waste cans.
    3. Failure to place hazardous waste into the appropriate waste container can result in an adverse chemical reaction.
- Exposure to <5% TMAH. TMAH is the active ingredient in some of the developers in the photolithography area.
- Exposure to <5% TMAH chemical can occur when:
    1. A member of the workforce does not have on the proper PPE when processing wafers with developers containing TMAH.
- Exposure to 5-25%% TMAH chemical can occur when:
    1. A member of the workforce does not have on the proper PPE when processing wafers with concentrated TMAH.
- Destruction or damage to tools causing impact to CINT Operations and delay of mission deliverables can
  occur when:
    1. Poorly designed tool parameters or the tool is operated outside of designed use.
    2. HMDS release can occur if a member of the workforce does not properly dispense HMDS in the approve spinner bench.
    3. During maintenance activity mixing standard chemicals in non-standard ways.
- Disposal of liquid wastes into the wrong waste stream.
- Removal of shields that prevent a direct exposure to high intensity ultraviolet light sources.
- Failure to properly monitor high pressure ultraviolet lamp intensity, applied power and service life can result in catastrophic lamp failure and severe damage to the light source and associated optics train.

What are the controls and how do you verify the controls are working?

Engineering Controls:

- The Engineering Controls in the Photo Lithography Processing Area include tool safety interlocks that are incorporated into the tool operating software and on doors.
- The Base wet bench and Solvent benches have tool interlocks that activate the emergency power off (EMO) and
  automatically shut down power to the benches if the interlocks are tripped or if Base or solvent

exhaust is lost.

- Sensors are also installed under the floor that will detect if the base bench is leaking.
- Chemicals are stored in ventilated enclosures.
- All effluent chemical waste is continuously monitored for pH level.
- Abnormal conditions in the AWN are immediately reported to EOC through the facilities management system to the building operator, and to IL Staff who performs daily operational checks, calibrations, etc., and are on-call 24/7 to respond to address issues.
- To minimize concerns when pouring photo resist from gallon bottles, the key operator will pour photoresist from the gallon bottles into smaller bottles for easy use.

- To minimize the potential for photoresist bottle breakage, users are trained to transport photoresist bottles from the refrigerator to the dispensing area and back with use of bottle carriers.

Administrative Controls

- Administrative procedures include written (revision controlled) operating procedures for each photo lithography tool that must be adhered to during operation or maintenance.
- An operator or maintenance person must be signed off by the Key Operator prior using or repairing the equipment.
- Documented and revision controlled training task lists developed by the Key Operator guide the trainer and trainee.
- Lock-Out-Tag-Out (LOTO) procedures are adhered to when performing equipment maintenance activities.
- The exhaust levels are determined through testing and by following published guidelines.
- The exhaust balancing and annual check are performed by Kirk Air, Inc. and follow Sandia's LEV protocol.
- Preventive maintenance schedules for each tool include a periodic check of the exhaust and verification
- of proper measurements.
- The solvent and base benches will alarm if exhaust is below a safe level or is inadvertently lost.
- A pressure gauge located on the exhaust connection to each processing bench provides a visual check for the presents of exhaust flow.
- Solvent bench hot plates and carboy level detectors are designed to prevent accidental ignition of hazardous vapor.
- All wet bench electrical enclosures are purged with nitrogen to prevent hazardous vapors from entering and to slow or stop flame propagation in the event of fire.
- All wet benches are equipped with ground fault interrupter outlets to prevent accidental electrocution.
- All wet bench power distribution schemes follow NEC guidelines to prevent fire due to component failure or circuit overload.
- Periodic exposure assessments performed by Sandia Corporate Industrial Hygiene group.
- Authorized use of a wet chemical processing tool in the CINT IL is administratively controlled through Training
- A user must be signed off by the Key Operator prior operating the equipment.
- All system interlock switches are checked and verified during maintenance activities.
- Work documents are periodically reviewed.
- LOTO procedures are inspected on a periodic basis.
- Exposure assessments have been performed by Sandia Corporate Industrial Hygiene group.

Examples of tools that may cause impact to CINT Operation and delay of access to processing resources:

- Contact Aligners could have mechanical/electrical failure. Although a service contract is in place, lack of
  readily available replacement parts can result in significant down time and impact to various users' experiment schedules.
- Photoresist Spinner benches could have mechanical/electrical failure. Replacement parts for the Spin
  benches are hard to find and in most cases are obsolete. This may cause significant down time and
  impact to various user experiment execution and data collection.
- As with any antiquated, "one of a kind" tool, user project deliverables can be impacted by any equipment related failure.

Personal Protection Equipment

- Training on the proper use of PPE and equipment operating procedures is required prior to authorization of use for the equipment.

Line Decision on Approval of the Safety Case (completed by management)

(Jeffrey Nelson, Manager-1131, for Neal Shinn, 1130, acting 1132) I was part of the work planning team and participated on the development of the safety case for this laboratory. I am comfortable with the level of critical thinking involved in the safety and hazard analysis of this laboratory. I also concur with the implementation of new Engineered Safety Controls (administrative and engineered) that have been implemented as a result of this Work Planning &Controls-Engineered Safety activity.

Jeffrey J. Nelson 9/17/2014

Safety Case #6: Metrology Area

How is the system defined?

- The metrology area is set up to provide trained users with equipment to perform
  1. In-line measurement
  2. Inspection
  3. Characterization
  4. Analysis of semiconductor products and/or process monitors (both whole and partial wafers).

What are the unacceptable consequences?

- Personnel injury from exposure to:
  1. High voltage
  2. Lasers
  3. Damage to tools causing impact to CINT Operations that result in the delay of access to processing resources.

How can the system fail?

- Exposure to equipment hazards can occur when:
  1. An Integration Laboratory Worker (ILW) defeats the tool safety interlocks and does not follow proper Lock-Out-Tag-Out (LOTO) procedures.
  2. An ILW exhibits lack of attention during day-to-day operations.
  3. Damage to tools causing impact to CINT Operations and delay of mission deliverables can occur if scheduled preventive maintenance (PM)s are not performed on time, such that preventable component failures become serious tool-down issues.
  4. Unapproved operation of an instrument without the proper training can lead to extensive damage to the instrument.

What are the controls and how do you verify the controls are working?

Engineering Controls

- Engineering controls for the metrology tools primarily consist of physical barriers to block access to the hazards,
  reinforced by interlocks. These include:

1. Lasers are fully enclosed and act as Class I systems during normal operation. Interlocks on the enclosure panels shut off the lasers when the panels are removed.
2. High voltage components are enclosed and interlocked to prevent contact with energized components during either normal operation or maintenance.
3. The high voltage and laser interlocks are tested at least annually to make sure they work.

Administrative Controls

- Administrative controls include the following operations that are governed by a range of technical work documents, such as:
  1. PHS
  2. Industrial Hygiene assessments
  3. hazard and barrier analyses
  4. Operating procedures
  5. On the job training (OJT) certification
  6. Tool install checklists
- Equipment-specific lockout/tag out procedures are in place or are written as needed for maintenance activities in
  which there is a risk of exposure to hazardous energy.
- Tools with lasers and/or high-voltage components have appropriate safety labels.

Line Decision on Approval of the Safety Case (completed by management)

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Jeffrey Nelson 9/17/2014

Continuous Improvement and Feedback

This OE document must be reviewed, revised (if necessary), and re-signed at least annually in conjunction with PHS renewal. This OE must be revised earlier in response to:

- new hazards (e.g. chemicals) being introduced in to the laboratory,
- recognition of hazards not previously considered, or
- identification of significant improvements to hazard control/mitigation defined in this document,

and other situations where improvement to laboratory safety should be documented. It should be noted that these same conditions may require revision of the laboratory PHS and required training matrix.

Reviews and Approval

Prepared by Laboratory Owner

John Nogan — John Nogan — 9/17/2014
Printed Name — Signature — Date

Reviewed by CINT ES&H Coordinator

Seth Nelson — [signature] — 9/17/14
Printed Name — Signature — Date

Additional SME Review required by Center ES&H Coordinator or Department Manager

Reviewer — Title/Activity — Signature — Date

Additional SME Review required by Center ES&H Coordinator or Department Manager

Reviewer — Title/Activity — Signature — Date

Approved by Department Manager

By approving the OE and Safety Case, the Department Manager attests that it is an appropriate assessment of the ES&H risks associated with the R&D activities that are authorized to take place in the designated lab(s). The approval signature further indicates that the hazard mitigations specified in this OE and Safety Case are also appropriate.

Jeffrey Nelson, 1131, for Neal Shinn, Acting Manger, 1132 — [signature] — 9/17/2014
Printed Name — Signature — Date

Laboratory Authorization Sheet:

Signature by the Authorized Workers in the following Summary Authorization Table certify that the worker has read, understood, and agree to follow the Operating Envelope identified in this document. Authorized Workers agree that they will not introduce hazards into this laboratory that are not covered by the PHS, OE, and related documents."

If a new MOW is brought in to work in the laboratory, their training must be evaluated by the Manager or Lab Owner prior to any work being assigned or conducted. Their signature asserts that this has been done.

Printed Name	Signature	Date	Lab Owner Confirm. (initials)	Chemical Operations	Environmental	Thermal Hazards	Mechanical Hazards	Non-ionizing Radiation (UV)						
