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Pollution Prevention Opportunity Assessment for MicroFab and SiFab Facilities at Sandia National Laboratories

Morgan Gerard

Prepared by
Sandia National Laboratories
Albuquerque, New Mexico 87185 and Livermore, California 94550

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Morgan Gerard
Environmental Management System
Sandia National Laboratories
P.O. Box 5800
Albuquerque, NM 87185-1050

Abstract

This Pollution Prevention Opportunity Assessment (PPOA) was conducted for the MicroFab and SiFab facilities at Sandia National Laboratories/New Mexico in Fiscal Year 2011. The primary purpose of this PPOA is to provide recommendations to assist organizations in reducing the generation of waste and improving the efficiency of their processes and procedures. This report contains a summary of the information collected, the analyses performed, and recommended options for implementation. The Sandia National Laboratories Environmental Management System (EMS) and Pollution Prevention (P2) staff will continue to work with the organizations to implement the recommendations.

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Acronyms and Abbreviations

AC200P	AC200 Plus
3-D	three dimensional
CMOS	complementary metal-oxide-semiconductor
DI	de-ionized
EMS	Environmental Management System
FY	Fiscal Year
gal	gallon
HF	hydrofluoric acid
HWMF	Hazardous Waste Management Facility
IPA	isopropyl alcohol
kg	kilogram
L	liter
lbs	pounds
MEMS	micro-electro-mechanical systems
MeOH	Methyl Alcohol
mL	milliliters
P2	pollution prevention
PPE	personal protective equipment
PPOA	pollution prevention opportunity assessment
PRS1000	PRS 1000 Photoresist Stripper
RCRA	Resource Conservation and Recovery Act
Sandia	Sandia Corporation
SNL/NM	Sandia National Laboratories/ New Mexico
TCLP	toxicity characteristic leaching procedure
TSDF	treatment storage and disposal facility
WIMS	Waste Information Management System

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Executive Summary

Center 1700 is responsible for the work performed and waste generated at the MicroFab and SiFab facilities at Sandia National Laboratories/New Mexico (SNL/NM). This Center is involved in producing microelectronics and providing services to Sandia Corporation's Strategic Management Units. Division 1000, of which MicroFab and SiFab are a part, is the largest generator of hazardous waste at the Laboratories. MicroFab and SiFab produce approximately 15 percent to the Division's hazardous waste. Therefore, a Pollution Prevention Opportunity Assessment (PPOA) was conducted to provide recommendations for possible waste reduction measures for MicroFab and SiFab. The PPOA team consisted of personnel from Sandia's Environmental Management System (EMS) team, MicroFab and SiFab, and Division 1000. The assessment team was responsible for evaluating processes and waste streams and generating pollution prevention (P2) opportunities.

A PPOA was conducted in Fiscal Year 2007 for Center 1700. Results of the PPOA included a 70 percent reduction of the primary waste stream and a 120,000 dollar overall cost savings per year. The results of the PPOA also contributed to a major de-ionized (DI) water reduction effort that ultimately reduced the use of 17 million gallons of DI water per year.

The largest waste stream generated in MicroFab and SiFab is now calcium fluoride. The PPOA team evaluated this waste stream and others for potential waste reduction, feasibility, applicability, and return on investment. Based upon this evaluation, four opportunity areas were selected for a more in-depth cost-benefit analysis. The MicroFab and SiFab opportunity areas are as follows:

Opportunity Area 1: Reduce Solvent Waste

Opportunity Area 2: Minimize Personal Protective Equipment (PPE) Waste

Opportunity Area 3: Recycle Calcium Fluoride Waste

Opportunity Area 4: Reduce Charcoal Contaminated with Arsenic and Organic Compounds

When implemented, opportunities within these areas will reduce the generation of hazardous waste, reduce solid waste, reduce regulatory liability and reporting requirements, improve operating efficiency, and provide an exceptional payback period on the initial investment in equipment and process changes.

Current chemical purchases and waste disposal costs for Opportunity Areas 1-4 are approximately 187,712 dollars per year. This cost will be reduced by approximately 69,500 dollars per year if these opportunities were implemented. It is estimated that the cost of implementation of the opportunities is minimal. No equipment purchases are necessary, only the implementation of administrative procedures, minor analytical costs, and minimal labor costs are required.

The total reduction in hazardous and chemical waste if all opportunities are implemented is approximately 3,400 kilograms (kg) per year.

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1. Introduction and Methodology

The Environmental Management System (EMS) staff and Pollution Prevention (P2) staff at Sandia National Laboratories/New Mexico (SNL/NM) conducts pollution prevention opportunity assessments (PPOAs) for SNL organizations. The goal of a PPOA is to identify practical, cost-effective strategies to do one or more of the following:

- Reduce overall resource use,
- Reduce or eliminate the generation of waste,
- Reduce waste volumes and toxicity,
- Increase purchasing of environmentally preferable material,
- Reduce energy and water consumption,
- Reduce the line organization's operational costs,
- Reduce regulatory liability, and
- Reduce personnel exposure to hazardous material.

The completed PPOA is presented to the organization for consideration and implementation. The EMS and P2 staff assists with implementation as much as possible through technical and administrative support and identifying funding options, when necessary.

This PPOA was conducted for MicroFab and SiFab at SNL/NM for Fiscal Year (FY) 2011. Review of data and reporting of all waste generators at SNL/NM identified MicroFab and SiFab as being one of the largest generators of hazardous waste for the site.

The primary purpose of this PPOA was to identify and recommend strategies and technologies to eliminate or reduce the hazardous waste streams generated by MicroFab and SiFab. For the purposes of this report, the term "hazardous waste" refers to chemical waste and waste defined as hazardous by the Resource Conservation and Recovery Act (RCRA).

The process used to perform this PPOA is outlined in Figure 1.

The PPOA team consists of staff members from the EMS, MicroFab and SiFab Management, Engineering, Maintenance, and the Center Facilities. All MicroFab and SiFab waste streams were reviewed and prioritized by weight. The waste streams were then evaluated for potential reduction options based on ease of implementation and return on investment. The assessment team was responsible for evaluating processes and waste streams and generating the P2 opportunities identified in this report. Information was collected through interviews with facility personnel, site visits, and evaluation of waste disposal and purchasing databases.

Alternatives were identified through discussion and brainstorming with key personnel and were then screened based upon feasibility and practicality.

Figure 1. PPOA Process Diagram

2. Facility Description

SNL/NM is a national security laboratory operated for the U.S. Department of Energy by Sandia Corporation (Sandia), a Lockheed Martin company. SNL designs non-nuclear components for the nation's nuclear weapons, performs a wide variety of energy research and development projects, and works on assignments that respond to national security threats both military and economic. The MicroFab and SiFab facilities are located at the SNL/NM site.

SiFab

SiFab is an 11,900-square foot Class 1 cleanroom for silicon wafer processing. The SiFab has processing expertise in both complementary-metal-oxide-semiconductor (CMOS) and micro-electro-mechanical systems (MEMS) technologies. The focus of the SiFab is the development, application and production of radiation-hardened CMOS integrated circuit technologies capable of realizing digital, analog, mixed-mode, and nonvolatile memory circuits. In addition, the silicon wafer fab supports development and production of Sandia's SUMMIT™ surface micromachining technology. The facility is capable of producing full-flow production lots with quick turnaround time as well as performing flexible process development. Additionally, the facility offers unique prototyping capabilities. Over 150 equipment sets are maintained, supported and operated 24 hours per day, 5 days a week (3 shifts). Both processing and maintenance expertise are staffed on all 3 shifts.

MicroFab

The MicroFab is a 14,900-square foot green-certified Leadership in Energy and Environmental Design or LEED® facility (for III-V compound semiconductor material processing, post silicon wafer processing and advanced packaging. The 6-inch silicon post-processing facility also supports glass and plastics processing, hybrid substrates and three-dimensional (3-D) integration. The MicroFab is designed for flexibility to allow development of a range of III-V compound semiconductor based optoelectronic, radio frequency, photonic and sensor microsystem technologies. Reconfigurable tools, many with little or no hardware changes required, allow for the processing of wafer pieces and full wafers up to 6-inch. All of the MicroFab equipment (180 tools) are maintained and supported by in-house maintenance and technical staff. The facility prototype's design and process alternatives perform highly customized, low-volume production with flexible processing capabilities.

Capabilities

- Photolithography Processes (Coat/Expose/Develop)
- Electron Beam Lithography
- Reactive Ion Etch
- Wet Etch/Clean
- Oxidation and Diffusion
- Thin Films
- Chemical Mechanical Polishing (CMP) for planarization
- Ion Implantation
- Metrology
- Deep Reactive Ion Etch
- Electroplating
- Packaging
- MEMS Release
- Yield Learning
- Statistical Process Control
- III-V Compound Semiconductor Epitaxial Growth
- Mixed-Technology Integration and Processing
- 3D Integration
- Materials Characterization
- Failure Analysis
- Wafer Bonding and Thinning

Professional Staff

The MicroFab and SiFab professional staff includes a core of Ph.D., Master, and Bachelor level scientists, engineers, and technicians who are experienced in a broad range of disciplines.

Disciplines include:

- microelectronic and micromachining process development
- equipment design
- materials engineering
- device physics
- chemical engineering
- sensor science
- circuit design
- computer science
- failure analysis
- reliability physics
- modeling and simulation engineering

3. Waste Streams

At SNL/NM, the two most costly generated wastes are known as “hazardous” and “chemical” wastes. For the purposes of this report, these waste types will be referred to collectively as hazardous waste. Hazardous wastes are tracked in a database from the point of generation to disposal. The database contains extensive information on each waste container including generating organization, contact, weight, and waste category. Generators are charged for the waste they generate. Waste costs in this report were estimated based upon current disposal costs and may not reflect actual charges.

A waste stream can be defined as a waste with consistent characteristics that is generated from a specific process. All primary waste streams of MicroFab and SiFab are considered hazardous.¹ The primary hazardous waste streams are depicted in the bar chart in Figure 2. The waste streams of MicroFab and SiFab are projected to cost nearly 400,000 dollars a year for disposal.² Waste generated from MicroFab and SiFab accounts for approximately 7 percent of SNL/NM’s total waste and about 15 percent of total disposal costs. For these reasons, a PPOA was recommended for MicroFab and SiFab.

3.1 MicroFab and SiFab Processes and Wastes

Figure 2 lists major waste streams generated from the MicroFab and SiFab and illustrates the comparative weight of each one. This PPOA considered potential waste reduction ideas for each of the waste streams. Figure 3 shows the top three MicroFab and SiFab waste streams in FY11, based upon weight of generated waste. These waste streams represent nearly 45 percent of the hazardous and chemical waste generated in MicroFab and SiFab.

The top three waste streams, by weight,

- Calcium Fluoride
- PRS1000
- Acetone/Isopropyl alcohol (IPA)/Methyl Alcohol (MeOH)/Photoresist

Figure 4 represents the chargeback cost for disposal of the top 10 waste streams in the MicroFab and SiFab.

¹ Calcium fluoride is listed in the (Waste Information Management System [WIMS] database) as a chemical waste even though it is a solid waste.

² MicroFab and SiFab were charged approximately 380,000 dollars waste generated as of 9-12-2011 of FY11 (WIMS database). Annual quantity was an extrapolation of the first three quarters of FY11.

Figure 2. Primary Hazardous Waste Streams by Weight (kg) of the MicroFab and SiFab for FY11

Figure 3. Top 3 Waste Streams of MicroFab and SiFab for FY11 (45 percent of MicroFab and SiFab Waste Streams)

Figure 4. MicroFab and SiFab Chargeback for FY11
(Waste descriptions from WIMS)

3.2 Previous and Recent Waste Reductions in Center 1700

3.2.1 Pollution Prevention Opportunity Assessment (June 2007)

A PPOA for Center 1700 was conducted in FY06 and the report was published in June 2007 (SAND2007-3420). At that time, Center 1700, which includes MicroFab and SiFab, was the largest hazardous waste generator at SNL/NM³. The three largest waste streams in FY06 were the PRS1000 Photoresist Stripper (PRS1000), EKC 265 Post Etch Residue Remover, and Hydrofluoric (HF) contaminated trash. In addition to these priority waste streams, the team identified significant opportunities to reduce water use.

Although, PRS1000 remains as one of the largest waste streams of the MicroFab and SiFab in FY11, the reductions that resulted from the previous PPOA were significant. The PRS1000 waste generated in FY06 was greater than 5,400 kg. Reduction opportunities implemented by

³ Center 1700 remains the largest generator of waste at SNL/NM in FY11.

the previous PPOA reduced the waste generated by 70 percent (over 3,750 kg reduction per year). This reduction accounted for an annual cost reduction of an estimated 120,000 dollars per year.⁴

Another opportunity that was successfully implemented was the reduction of water use at the wet bench rinse baths. The DI rinse baths were being dumped more than twice as often as the industry standard. Additionally, the trickle bypass flow or weeping of the DI water baths to prohibit bacterial growth was also twice that of industry standards. These processes, as well as others, were optimized and contributed to a 17 million gal per year reduction in DI water use. The DI Water Reduction Team that implemented the reductions won the 2008 national Nuclear Security Administration Best-in-Class Award.

The last opportunity implemented from the 2007 PPOA was the recycling of incoming wafer containers or “coin boxes”. These wafer containers are now recycled at the Solid Waste Transfer Facility rather than being disposed in the landfill.

3.2.2 Recent and Ongoing Waste Reductions

Shoe cover racks in the SiFab pre-gown area, and in the MicroFab Locker Rooms have recently been installed. For those who are in and out of the cleanroom on a frequent basis, these racks can be used to store an individual's shoe covers, allowing them to be worn multiple times before requiring laundering. The shoe covers will be pulled, and laundered, on a weekly basis. Use of these racks will reduce the consumption of costly DI water, soap, and electricity. It is estimated that approximately 15 loads of laundry are saved per week because of the newly installed racks or approximately 26,520 gal of DI water per year.

When retrofits, equipment removals, and renovations occur in the MicroFab and SiFab, the end result is irregular waste streams. These waste streams may be comprised of old equipment, ducting, and piping, which often are contaminated with residual chemicals. Personnel at the MicroFab and SiFab have established a process to review and analyze the waste streams. In the past two years, ducting removed from mainly acid wet benches has been through this process. Ducting was cut, tested, and neutralized, when necessary, and has been disposed of as solid waste. In years past, all this material would have been considered hazardous and disposed of as such, increasing the volume of hazardous waste streams at the MicroFab and SiFab significantly. It is estimated that, beyond the elimination of intensive hazardous waste processing, the waste stream review and analysis effort has saved the organization 30,000 dollars in hazardous waste disposal costs in the past two years.

3.3 Priority Processes and Waste Streams Considered for this PPOA

For this PPOA, the three largest (by weight) hazardous waste streams listed in Section 3.1 were evaluated. When reviewing all of the process waste data for MicroFab and SiFab over a period nine months, or three quarters, the top three waste streams stood apart from the others. Seventy

⁴ An estimated \$27,000 in disposal costs per year and \$96,000 per year in purchasing costs, at \$96 per gal for PRS1000.

percent of the total waste generated, by weight, at MicroFab and SiFab were the Calcium Fluoride, Acetone/IPA/MeOH/Photoresist, and PRS1000. A review of the processes provided valuable information for the Pollution Prevention Ideas and Opportunities section of this report.

3.3.1 Calcium Fluoride Waste

The calcium fluoride waste stream is a result of a chemical precipitation process extensively used in the semiconductor industry. HF is used in large quantities in the MicroFab and SiFab and the fluoride effluent is strictly controlled by local waste water regulations. Therefore, with the appropriate approval, the HF waste streams are converted to a non-hazardous solid waste; calcium fluoride. Approximately 2,000 kg of calcium fluoride was disposed of during FY11.⁵

3.3.2 Acetone/IPA/MeOH/Photoresist Waste

The waste stream for the acetone, IPA, MeOH, and photoresist mixture originates from the processing and cleaning of wafers, MEMS and other devices. It also originates from the cleaning and maintenance of the wafer and device processing equipment. Therefore, the waste stream is a liquid mixture, and not from one distinct source, and must be treated as such.

All operations involving the flammable and hazardous liquids associated with this waste stream must be performed under solvent exhaust to eliminate any fumes. Some of the liquid evaporates into the solvent exhaust during the process, so the quantity of the incoming liquid solvent may not be equal to the quantity of mixed solvent waste. Because of the hazardous fumes and the evaporation in this waste stream, the processing and cleaning containers usually have covered lids and are normally stored under solvent exhaust.

The liquid photo resist associated with wafer production is typically dropped onto a spinning wafer to obtain a more uniform coating. Consequently, the excess liquid is discharged off of the side of this spinning “plate”. The cleaning and maintenance of the tools involved with this process is also performed under the solvent exhaust and typically involves a fume hood. The cleaning uses a significant amount of acetone and IPA.

All liquids involved with the above processes are captured in metal liquid containers. They are stored in a labeled container called a carboy or are directly piped into a 35 gal container designated for this waste stream. The containers are temporarily stored in a less than 90-day storage area and are disposed of by properly trained personnel.

3.3.3 PRS1000 Waste

PRS1000 Photoresist Stripper is used to remove resist and/or polymer from wafers. The removal processing is performed in the clean room photo-process area. The PRS1000, though mainly consisting of water, contains some hazardous solvent components such as 1-methyl-2-pyrrolidinone and tetrahydrothiophene-1, 1-dioxide. The combination of these two compounds creates an effective solvent polymer stripper. Furthermore, solvent components such as these require proper hazardous waste disposal since they cannot be sent to municipal sewer.

⁵ Recycling of calcium fluoride was implemented as a result of this PPOA in July 2011.

The PRS1000 waste stream is currently the third largest hazardous waste stream within MicroFab and SiFab. Approximately, 144 kg per month or nearly 1,730 kg per year are disposed of as hazardous waste. PRS1000 was the number one waste stream in FY06 with nearly 5,480 kg per year disposed of as hazardous waste. Efforts resulting from the previous PPOA (Pollution Prevention Opportunity Assessment for Organization 1700, SAND2007-3420) managed to reduce this hazardous waste stream by nearly 70 percent. It was determined at the onset of this PPOA effort that the PRS1000 waste stream had been thoroughly evaluated and the process optimized. Therefore it did not require any further reduction effort.

4. Pollution Prevention Ideas and Opportunities

After evaluating the waste stream data and brainstorming with team members, a list of potential waste reduction ideas were developed. The team reviewed the priority processes and waste streams and identified several other that are identified, evaluated, and are summarized below:

- Idea 1: Reduce solvent waste by,
 - Optimizing AC200 Plus (AC200P) process.
 - Optimizing Litho 1 & 2 tool processes.
- Idea 2: Minimize waste of HF and other contaminated material by,
 - Creating a waste profile through Hazardous Waste Management Facility.
 - Optimizing the process.
- Idea 3: Minimize personal protective equipment (PPE) waste by,
 - Extending the use of the PPE.
 - Increasing awareness and re-training.
- Idea 4: Recycle some solvent waste streams as fuel by,
 - Selling solvent waste to Treatment, Storage and Disposal Facility (TSDF).
- Idea 5: Recycle Calcium Fluoride waste stream by,
 - Creating a new recycle stream.
- Idea 6: Reduce a Charcoal contaminated with arsenic waste stream by,
 - Analyzing samples and sending non-RCRA waste to landfill.
- Idea 7: Reuse sandblaster abrasive,
 - Extend the use of sandblaster media.

Ideas 4 and 7 were rejected for the following reasons:

- Idea 4: An energy credit was pursued through the SNL/NM Hazardous Waste Management Facility (HWMF) for some solvent waste streams at the MicroFab and SiFab. The British Thermal Units potential of these waste streams could be used as a fuel at the TSDF rather than disposed of as hazardous waste. It was determined that this was not an available option by the HWMF.
- Idea 7: The sandblaster is used a couple of times a year to clean the shielding of evaporators and sputter machines. The process owner stated that the “blast media is recycled until it is a very fine powder and is no longer useful to the blaster.”

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5. Description and Analysis of P2 Opportunities

5.1 Opportunity 1: Reduction of Solvent Use

5.1.1 Optimizing Process for ACS200P Track Tool

The ACS200P Track tool is a dual robot automated cluster system designed to meet customer's needs for clean, reliable, high-throughput photolithography processing. The ACS200 Track tool system is equipped with sender/receiver cassette stations and modules for hexamethyldisilazane vapor priming, spin coating, puddle developing, solvent based cleaning, and hot plate baking and cooling. The tool can process wafers from 4 to 6 inches in diameter in all process modes, simultaneously. All solvents used for wafer strips and resist bowl cleans are captured in a 3 gal holding tank in the service chase. If the holding tank gets full it will render the track inoperable until the tank can be pumped out.

Using the current recipe to clean the resist bowl requires operators to process two wafers per clean resulting in the use of 394 grams of acetone per run. This is based upon a flow rate of 125 milliliters (mL) per minute and a 120-second dispense. Implementation of the new recipe requires the operator to process one wafer per clean resulting in 213 grams of acetone per run. This is based on flow rate of 125 mL per minute and a 130-second dispense. A slightly longer dispense time is sufficient to clean the bowl.

For 8 months, 1,120 clean runs with the 2 wafers per bowl recipe resulted in the use of 116 gal of acetone use. The new, one wafer recipe uses only 63 gal in the same amount of time. This is a 45 percent reduction in solvent waste and time spent pumping the holding tank.

The change in the cleaning results in a reduction of approximately 79.5 gal or 234 kg of solvent waste per year and annual savings of approximately 11,000 dollars per year. Purchasing of acetone will also be reduced and save an estimated 2,100 dollars per year.⁶

Note: Disposal costs and dollar savings are based on FY11 charges provided by the HWMF.

5.1.2 Optimize processes for resist types

There are also plans to reduce solvent waste even more by setting up clean programs specific to resist types. The resists currently plumbed on the ACS200P Track tool vary from very high to low viscosity and clean times could be adjusted for each viscosity type.

The same approach described in Section 5.1.1 can be applied to the Strip Resist wafer recipe, which utilizes acetone and MeOH. This change will result in a 58 percent reduction over the current process. These two recipes have measurable reductions in solvent waste and also will decrease the amount of time for maintenance involvement in pumping of the holding tank.

⁶ This opportunity was implemented during July FY11.

This opportunity will result in a reduction of approximately 38 gal or 110 kg and a savings of 5,000 dollars per year. Purchasing of solvents will also be reduced and save an estimated 1,000 dollars per year.⁷

5.1.3 Optimizing Process for Litho #1 & #2 Metal Liftoff Tools

One of the metal lift-off processes used in the MicroFab requires soaking a wafer in a solvent (e.g. N-Methyl-2-pyrrolidone, PRS3000 Photoresist Stripper, and acetone) for various amounts of time. For 6-inch wafers, this typically means manually using a large container or beaker to collect between 200 and 2,000 mL of solvent per wafer. Over a period of a year, this accounts for approximately 200 to 300 liters (L) of solvent. All of this solvent is discarded as hazardous waste after the process is complete (i.e. single use), resulting in a significant contribution to the solvent waste generated at the facility. There are established automated system processes that could replace this manual process for 6-inch wafers. These automated systems are called SS1 and SS2 and they are set up to always reuse the solvent, occasionally adding fresh solvent to make up for losses of about 50 mL per wafer. In other words, 3 to 4 – 6-inch wafers can be processed with the same amount of solvent used to process 1 wafer using the manual process.

The automated system also eliminates the need to use wipes to clean the containers and wipe up small spills that may occur when transferring solvent. Therefore, the hazardous contaminated material waste stream is reduced.

If all of the manual processes for 6-inch wafers can be replaced with the established automated system, approximately 70 percent or 140 to 210 L, of solvent (109 – 162 kg) could be removed from the hazardous waste stream. For disposal costs alone, the annual savings of an estimated are estimated at 5,000 to 7,500 dollars per year. Purchasing of solvents will also be reduced and will save an estimated 1,100 dollars per year.

5.2 Opportunity 2: Minimize PPE Waste

5.2.1 Minimize Waste of HF-Contaminated Material

When wet benches are used to process wafers, operators are required to wear the appropriate PPE. The current procedure, Chemical Handling and Personal Protective Equipment for 858EF/858N Fabs, states: “gloves and other disposable PPE (e.g., disposable aprons, sleeve guards) shall be disposed of at the end of the day or when the task being conducted is complete. Torn Nitrile gloves shall be replaced immediately. Trionic gloves that have had no or light contact with chemicals shall be rinsed in a glove wash and re-used for the duration of the shift; at the end of the shift, these gloves may be rinsed and disposed of in the non-hazardous waste cans. If PPE is contaminated with hazardous chemicals it shall be disposed of in the appropriate hazardous waste container.”

The current procedure suggests that there should be a minimal amount of contaminated hazardous waste regarding PPE from the MicroFab and SiFab. Yet, gloves comprise

⁷ This opportunity was implemented during July of FY11.

approximately 50 percent of the HF-contaminated material waste stream, as well as, other acid, base, and solvent hazardous material waste streams. The team believes that, although a procedure is in place, users of PPE remain very conservative when disposing of PPE and continue to dispose of it in the hazardous waste bins.

There is an opportunity to work with the HWMF and Environmental Compliance Coordinators in creating a Profile process. This Profile process will determine, through process knowledge and initial analytical work, the disposal description of the contaminated material waste streams in question. The team believes that a waste profile for the Photo Lift Bay and the Acid Bay will reveal that the PPE now disposed of as hazardous waste is actually non-hazardous. Currently, the Photo Lift Bay and the Acid Bay produce five 5-gal bags of hazardous contaminated material per week or a total of 5 to 10 kg of waste per week.

This opportunity will result in a reduction of approximately 250 to 500 kg of hazardous waste and a savings of 11,000 to 19,500 dollars per year if the PPE is determined to be non-hazardous and disposed of at the local landfill.

5.2.2 Minimize PPE Waste with the use of clips

Gloves used as PPE in the MicroFab and SiFab are often left on wet benches during breaks or in between process tasks. There is a greater likelihood that gloves will become contaminated or presumed to be contaminated when left on the wet benches. Using clips to hang gloves near the benches will likely extend the life of gloves during the shift and reduce the quantity of gloves in the hazardous waste stream.

It is estimated by the team that glove life would be extended 2 to 3 times its current use. This opportunity, in addition to further awareness and training, will result in a reduction of approximately 250 - 500 kg (assuming a conservative 50 percent reduction estimate) of hazardous waste and a savings of 11,000 to 19,500 dollars per year. An additional estimated 4,500 to 9,100 dollars would be saved on the purchase of gloves.

5.2.3 Minimize PPE Waste with Awareness and Training

Additional emphasis on the proper disposition of PPE through training and job aids was determined to be a good opportunity for improvement. Producing job aids and reminders of how to manage and dispose of PPE will help in the reduction of hazardous waste.

5.3 Opportunity 3: Recycle Calcium Fluoride Waste

Calcium Fluoride is the largest waste stream from the MicroFab and SiFab. In 2007, when the PPOA for Center 1700 was conducted in 2007 calcium fluoride was not considered a priority waste stream based upon the quantity generated at that time. In the first three quarters of FY11, 1,899 kg (projected to be 2,000 kg for the full FY) had been disposed of in the local landfill. Calcium fluoride is a product of a chemical precipitation process used widely in the semiconductor industry and other industries that use large amounts of HF. The conversion from HF to calcium fluoride generates a non-hazardous cake.

The team was aware that Intel Corporation and specifically, the Fab located in Rio Rancho, New Mexico, also produced calcium fluoride cake in amounts much larger than that of SNL/NM. The team decided to contact Intel to determine their calcium fluoride disposition path and learned that Intel sends their cake to a company to be recycled for use in road materials. Further investigation determined that the HWMF at SNL/NM uses the same vendor as Intel-Rio Rancho to send hazardous waste. Based upon this determination the MicroFab and SiFab implemented a calcium fluoride cake recycling program in July 2011.

Although, the cost savings is minimal (HWMF charges 6.50 dollars per kg for recycle compared to 7 dollars per kg for landfill), at approximately 1,000 dollars per year the largest waste stream in Center 1700 is now recycled rather than being disposed of in the landfill.

5.4 Opportunity 4: Reduce Charcoal Contaminated with Arsenic and Organic Compounds

The charcoal contaminated with arsenic and organic compounds waste stream is one of the largest and most expensive waste streams generated from the MicroFab and SiFab. Charcoal is used to scrub the exhaust from a particular set of tools that potentially contain organic compounds. An opportunity to perform a toxicity characteristic leaching procedure (TCLP) for each batch of charcoal contaminated with arsenic waste may show that the organics in the charcoal are below the landfill limit requirements.

A total of 466 kg of charcoal contaminated with arsenic and organic compounds was disposed of as hazardous waste in FY11, at a disposal cost of 21,565 dollars. If the TCLP reveals that this waste stream is non-hazardous for all samples, the waste could be sent to the local landfill and the total estimated cost of disposal would drop to 4,760 per year or an annual savings of 16,800 dollars.

6. Conclusion

The four areas and their subsequent opportunities identified in this report can significantly reduce the cost and waste generation rates in MicroFab and SiFab. All opportunities can be implemented with relatively little or no upfront cost.

This PPOA was conducted because MicroFab and SiFab generates approximately 15 percent to the Division's hazardous waste. Additionally, the waste streams of MicroFab and SiFab are projected to cost nearly 400,000 dollars per year for disposal. Waste generated from MicroFab and SiFab accounts for approximately 7 percent of the SNL/NM's total waste and about 15 percent of the total disposal cost.

The team identified several opportunities for improvement in hazardous waste volume disposal and cost savings. If all the identified opportunities were to be implemented there would be an estimated reduction of approximately 3,419 kg of hazardous waste and combined savings of disposal and purchasing costs of 69,500 dollars per year.

Table 1. Opportunities and their estimated annual reductions and savings

Section	Opportunity (Conservative estimates used for opportunities where there was a reduction range)	Waste Reduced (kg/year)	Disposal Cost Savings (Dollars/year)	Purchase Cost Savings (Dollars/year)
5.1.1	Optimizing Process for ACSPlus 200 Track Tool	234	11,000	2,100
5.1.2	Optimize processes for resist types	110	5,000	1,000
5.1.3	Optimizing Process for Litho #1 & #2 Metal Liftoff Tools	109	5,000	1,100
5.2.1	Minimize Waste of HF Contaminated Material	250	11,000	0
5.2.2, 5.2.3	Minimize PPE with the use of clips, Minimize PPE waste with Awareness and Training	250	11,000	4,500
5.3	Recycle Calcium Fluoride Waste	2,000	1,000	0
5.4	Reduce Charcoal Contaminated with Arsenic and Organic Compounds	466	16,800	0
Total		3,419	60,800	8,700

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Attachment 1

Calculations and Assumptions

CALCULATIONS AND ASSUMPTIONS:

Calculations and Assumptions for Pollution Prevention Opportunity Assessment for MicroFab and SiFab Facilities at Sandia National Laboratories

ASSUMPTIONS:

PRS1000 Photoresist stripper weighs the same amount as water with a specific gravity of 1.07 (from PRS1000 MSDS).

The average cost of a solvent is \$25/gal (Acetone--\$26.90, IPA—\$25.46, MeOH—\$23.96)
Solvents are 6.5 pounds (lbs.) per gal.

CALCULATIONS FOR SECTION 3 - WASTE STREAMS

Building 858N, 858EF, 858 Hazardous Waste Building (MicroFab and SiFab Waste – Category C8, C9 from WIMS database): 11,655 kg from 10-1-10 to 9-12-11. Disposal Charge Amount: \$329,846. Not all chemical and hazardous waste was recorded at the time of the data pull. The likelihood is that the data represented is for 10-1-10 to approximately 9-1-11 and not 9-12-11. Historically, it takes about two weeks from the disposal date to receive the final quantity and cost for a particular time period in the WIMS database. Therefore, the total FY11 cost and disposal records will not be available until approximately 10-15-11 and the estimated total cost per year for MicroFab and SiFab will be approximately \$400,000.

MicroFab and SiFab: 15% of Division 1000 chemical and hazardous waste: 11,655/77,496
Division 1000 for chemical and hazardous waste (Category C8, C9 from WIMS database):
77,496 kg from 10-1-10 to 9-12-11.

MicroFab and SiFab: 7% of SNL/NM chemical and hazardous waste: 11,655/165,397
Building 858N, 858EF, 858 Hazardous Waste Building (MicroFab and SiFab Waste – Category C8, C9 from WIMS database): 11,655 kg from 10-1-10 to 9-12-11.

CALCULATIONS FOR SECTION 3.2.1- POLLUTION PREVENTION OPPORTUNITY ASSESSMENT (June 2007)

Quantity of PRS1000 disposed of in FY06 = 5,480 kg
Quantity of PRS1000 disposed of in FY11 = 1,730 kg
Difference in weight: 3,750 kg or a 70% reduction
Cost savings per year with 2011 rates: $3,750 * \$7.19 = \$26,962$
Purchase price of PRS1000 is \$96/gal
 $\$96/\text{gal} * \text{gal}/8.4 \text{ lbs} * 2.2 \text{ lbs}/\text{kg} = \$25/\text{kg}$
PRS1000 specific gravity is approximately equal to water (1.07 from MSDS)
 $3,750 \text{ kg} * \$25/\text{kg} = \$93,750/\text{year savings}$
Total savings: $93,750 + 26,962 = \$120,700/\text{year}$ (calculation is executive summary as well)

The annual savings for the 2006 PPOA are mainly contributed to the reduction of PRS1000 Photoresist Stripper reduction. The disposal cost reduction is approximately \$27,000 (3,750 kg reduction times the current cost of disposal for PRS1000 at \$7.17/kg which equals \$26,962 or approximately \$27,000). The purchase price for PRS1000 is \$96/gal or \$25/kg (\$96/gal x 1gal/8.4 lbs. x 2.2 lbs/kg). Therefore, 3,750 kg reduction of PRS1000 x \$25/kg = \$93,750 savings per year. The sum of the disposal and purchase price cost reductions is approximately \$120,000 per year.

CALCULATIONS FOR SECTION 3.1- MICROFAB AND SIFAB PROCESSES AND WASTES

Acetone/IPA/MeOH/Photoresist is: 1,658 kg from 10-1-10 to 9-12-11

Calcium fluoride is: 1,958 kg from 10-1-10 to 9-12-11

PRS1000 is: 1,729 kg from 10-1-10 to 9-12-11

Total of the Top three is: 5,345 kg

Top three comprise 45% of SiFab and MicroFab Hazardous and Chemical Waste

CALCULATIONS FOR SECTION 3.3.1 CALCIUM FLUORIDE WASTE

Calcium Fluoride disposal weight from 10-1-10 to 9-12-11 was 1,958 kg. This number was rounded up to approximately 2,000 kg disposed of per year on average.

CALCULATIONS FOR SECTION 5.1.1- OPTIMIZING PROCESS FOR ACS200 PLUS TRACK TOOL

6.5 lbs of acetone/gal * kg/2.2 lbs = 2.95 kg/gal

116 gal of acetone/8 month = x/12 month = 174 gal acetone/year (old process)

63 gal of acetone/8 month = x/12 month = 94.5 gal acetone/year (new process)

174 gal of acetone- 94.5 gal of acetone = 79.5 gal of acetone/year reduction

79.5 gal of acetone /year * 2.95 kg/gal = 234 kg of solvent/year

234 kg of acetone /year * \$46/kg disposal cost = \$10,788/year savings (disregards packaging costs). Rounded to \$11,000.

Purchase price at \$27/gal for acetone: 79.5 kg * \$27 = \$2,146/ year saved on purchasing costs. Rounded to \$2,100.

CALCULATIONS FOR SECTION 5.1.2 - OPTIMIZE PROCESSES FOR RESIST TYPES

6.5 lbs of solvent/gal * kg/2.2 lbs = 2.95 kg/gal

Before change to process is made:

Acetone + MeOH (MeOH) = 123 mL + 71 mL = 194 mL

0.194 L of solvent used * 1250 wafers processed = 243 L

After change to process has been made:

Acetone + MeOH = 46 mL + 35 mL = 81 mL

0.081 L of solvent * 1250 wafers processed = 101.25 L

Solvent saved per year: 243 L-101 L=142 L

142 L (1 gal/3.785 L) = 38 gal of solvent

6.5 lbs/gal of Solvent * kg/2.2 lbs = 2.95kg/gal of solvent

38 gal * 2.95 kg = 112 kg

112 kg * \$46/kg = \$5,152/ year in disposal costs. Rounded to \$5,000.

At \$27/gal purchase price the savings is 38 gal * \$25/gal of solvent = \$950/ year. Rounded to \$1,000.

CALCULATIONS FOR SECTION 5.1.3 - OPTIMIZING FOR LITHO #1 & #2 METAL LIFTOFF TOOLS

6.5 lbs of solvent/gal * kg/2.2 lbs = 2.95 kg/gal

140 to 210 L of solvent used

140 L * gal/3.785L = 37 gal of solvent (min)

210L * gal/3.785 = 55 gal of solvent (max)

37 gal * 2.95 kg/gal = 109 kg of solvent (min)

55 gal * 2.95 kg/gal = 162 kg (max)

109 kg * \$46/kg = \$5,014 minimum saved/ year in disposal costs. Rounded to \$ 5,000.

162 kg * \$46/kg = \$7,452 max saved/ year in disposal costs. Rounded to \$7,500

Purchase costs reduced: 37 gal * \$25/gal solvent (average mix) = \$925/ year (min)

Purchase costs reduced: 55 gal * 25/gal solvent (average mix) = \$1,375/ year (max). Rounded to \$1,100 average.

CALCULATIONS FOR SECTION 5.2.1 -MINIMIZE WASTE OF HF-CONTAMINATED MATERIAL

500 kg * (\$46/kg RCRA) – 500 kg * (\$7/kg non-RCRA) = \$19,500 savings per year if all HF-contaminated waste is deemed non-hazardous

Conservative estimate (minimum reduction) is \$250/kg which would be \$10,750 kg/ year saved. Rounded to \$11,000 used.

CALCULATIONS FOR SECTION 5.2.2 - MINIMIZE PPE WASTE WITH THE USE OF CLIPS

Cost of Nitrile Gloves (gloves are estimated at 50% of contaminated trash waste stream or approximately 500 kg):

24 lbs/case of 72 pairs of nitrile gloves

24 lbs = 10.9 kg

Remove box and packaging: 10 kg/72 pair of gloves

500 kg (\$182/10 kg) = \$9,100 (gloves at 50% of contaminated trash waste stream) as the majority of the weight are gloves.

250 kg = \$4,550 (gloves at 25% of contaminated trash waste stream) (500 kg * \$46/kg) – (500

kg * \$7/kg) = \$19,500 savings per year if all HF contaminated waste is deemed non-hazardous

Conservative estimate is (\$250/kg * \$46/kg) – (250 * \$7/kg) which would be \$10,750 kg/ year saved. Rounded to \$11,000.

PPE (contaminated lab trash):

Lab trash contaminated with acids including HF: 315 kg

HF contaminated material: 69.8 kg

Gallium arsenide/ sodium hydroxide-contaminated lab trash: 43.6 kg

Gallium arsenide/ MeOH-contaminated trash: 27 kg

Gallium arsenide/indium antimonide-contaminated material: 14.1 kg

Gallium arsenide/HF-contaminated material: 159 kg

Gallium arsenide/ antimony-contaminated lab trash: 24.2 kg

Gallium arsenide-contaminated material: 132 kg

Acetic acid/arsenic/HF-contaminated material: 155 kg

Acetic- contaminated lab trash: 18.1kg

Total: 957.8 kg. Rounded to 1,000 kg

50% of total are gloves (assumed): used 500 kg

Total disposal cost: \$44,059 or \$46,000 using 1,000 kg of waste per year.

Total disposal cost:

Approximate purchase cost of PPE per year is 957.8 kg (used 1,000). $1,000 * (\$182 \text{ [cost of gloves]/10 kg}) = \$18,200/\text{year}$. 50% of waste stream is assumed to be gloves. \$9,100 per year reduction.

CALCULATIONS FOR SECTION 5.3 - RECYCLE CALCIUM FLUORIDE WASTE

2,000 kg/year to landfill * \$7/kg = \$14,000

2,000 kg/year recycled * \$6.50 = \$ 13,000

= \$1000/year savings

CALCULATIONS FOR SECTION 5.4 -REDUCE CHARCOAL CONTAMINATED WITH ARSENIC AND ORGANIC COMPOUNDS

466 kg for FY11 (total of 3 waste batches)

TCLP = \$500

466 kg * \$46/kg = \$21, 436

\$21, 565 – (\$500 * 3 batches) = \$19,936

\$19,936 (current disposal charges – (\$466 kg * \$7/kg for landfill) = \$16,674 saved per year if all batches are determined to be non-hazardous.

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