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Pollution Prevention Opportunity Assessment for Organization 1700

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Prepared by
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Pollution Prevention Opportunity Assessment for Organization 1700

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Abstract

This Pollution Prevention Opportunity Assessment (PPOA) was conducted for Sandia National Laboratories/New Mexico Organization 1700 in June, 2006. The primary purpose of this PPOA is to provide recommendations to assist Organization 1700 in reducing the generation of waste and improving the efficiency of their processes and procedures. This report contains a summary of the information collected, analyses performed and recommended options for implementation. The Sandia National Laboratories Pollution Prevention staff will continue to work with Organization 1700 to implement the recommendations.

Acknowledgements

The author thanks Don “Quatro” Baker IV, Bess Campbell-Domme, Javier Chavez, Linda Dailleboust, Sally Douglas, Larry Hatcher, Jack Mizner, Rick Saiz, and Dean Tulk.

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Acronyms and Abbreviations

AWNS	Acid Waste Neutralization System
BEOL	Back End of Line
CAD	Computer Aided Design
CMOS	Complementary Metal-Oxide-Semiconductor
CMP	Chemical Mechanical Polishing or Planarization
CVD	Chemical Vapor Deposition
DOE	Department of Energy
DUV	Deep Ultraviolet
EKC-265	a post etch residue remover
FEOL	Front End of Line
HDPE	High density polyurethane
IC	Integrated circuit
IMEMS	Integrated Micro-Electro-Mechanical Systems
MDL	Microelectronics Development Laboratory
MEMS	Micro-Electro-Mechanical Systems
MESA	Microsystems and Engineering Sciences Applications
P2	Pollution Prevention
PPE	Personal Protective Equipment
PPOA	Pollution Prevention Opportunity Assessment
PRS1000	Photoresist Stripper 1000
PVD	Physical Vapor Deposition
ROI	Return on investment
SNL/NM	Sandia National Laboratories New Mexico
SWEIS	Site wide environmental impact statement
SWTF	Solid waste transfer facility
WB	Wet bench

Executive Summary

Organization 1700 is responsible for Microsystems Science, Technology, and Components at Sandia National Laboratories/ New Mexico. This organization is involved in producing microelectronics and providing services to Sandia's Strategic Management Units.
Division 1000, of which Organization 1700 is a part of, is the largest generator of hazardous waste at the laboratory. Organization 1700 contributes approximately 30% to the Division's hazardous waste volume. Therefore, a Pollution Prevention Opportunity Assessment (PPOA) was conducted to provide recommendations for possible waste reduction measures for Organization 1700. The PPOA team consisted of personnel from Pollution Prevention (P2), Organization 1700, and Division 1000. This assessment team was responsible for evaluating processes and waste streams and generating P2 opportunities.

The largest waste stream generated in Organization 1700 is its PRS-1000 Photoresist Stripper. This chemistry is used in both the Front End of Line (FEOL) and Back End of Line (BEOL) processes at the Microelectronics Development Laboratory (MDL) and comprises 30% of Organization 1700's hazardous waste streams. The PPOA team evaluated this waste stream and others for potential waste reduction, feasibility, applicability, and return on investment. Based upon this evaluation, five opportunities were selected for a more in depth cost-benefit analysis. When implemented, these opportunities will reduce the generation of hazardous waste; reduce water use, reduce regulatory liability and reporting requirements, improve operating efficiency, and provide an exceptional payback period on the initial investment in equipment and process changes. The opportunities are as follows:

Opportunity 1: Optimization of the PRS-1000 Photoresist Stripping Process
Opportunity 2: Minimizing HF Contaminated Waste Stream
Opportunity 3: Eliminating Acetone Contaminated Waste Stream
Opportunity 4: Water Reduction at Rinse Baths
Opportunity 5: Recycling Wafer Containers

Organization 1700's current approximate costs for Opportunities 1-3 is $198,600 per year in chemical purchases and disposal costs. This cost will be reduced to approximately $44,500 per year if these Opportunities were implemented. The cost of implementation of the Opportunities is estimated at $185,000 (equipment, installation, and start-up/testing). In addition, Opportunity 4 will reduce approximately 500,000 gallons of water use per year. Water use at Sandia as a whole is nearing the limits of the SWEIS and the MDL is the greatest user at 14.9%.

1. Introduction and Methodology

The Pollution Prevention (P2) staff of Sandia National Laboratories/New Mexico (SNL/NM) conducts pollution prevention opportunity assessments (PPOAs) for Sandia 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
- Reduce personnel exposure to hazardous material

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

This PPOA is being conducted for Organization 1700 at Sandia National Laboratories/New Mexico (SNL/NM) for FY07. Review of data and reporting of all waste generators at SNL/NM has identified Organization 1700 as being one of the largest generators of hazardous waste for the site.

The primary purpose of this PPOA is to identify and recommend strategies and technologies to eliminate or reduce the hazardous waste streams generated by Organization 1700. For the purposes of this report, the term "hazardous waste" refers to both waste defined as hazardous by the Resource Conservation and Recovery Act.

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

The PPOA team consists of staff members from P2, Organization 1700 Management, Engineering, Maintenance, and the Hazardous Waste Management Facility. All Organization 1700 waste streams were reviewed and prioritized by volume. These waste streams were then evaluated for potential reduction options based on potential ease of implementation and high 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.

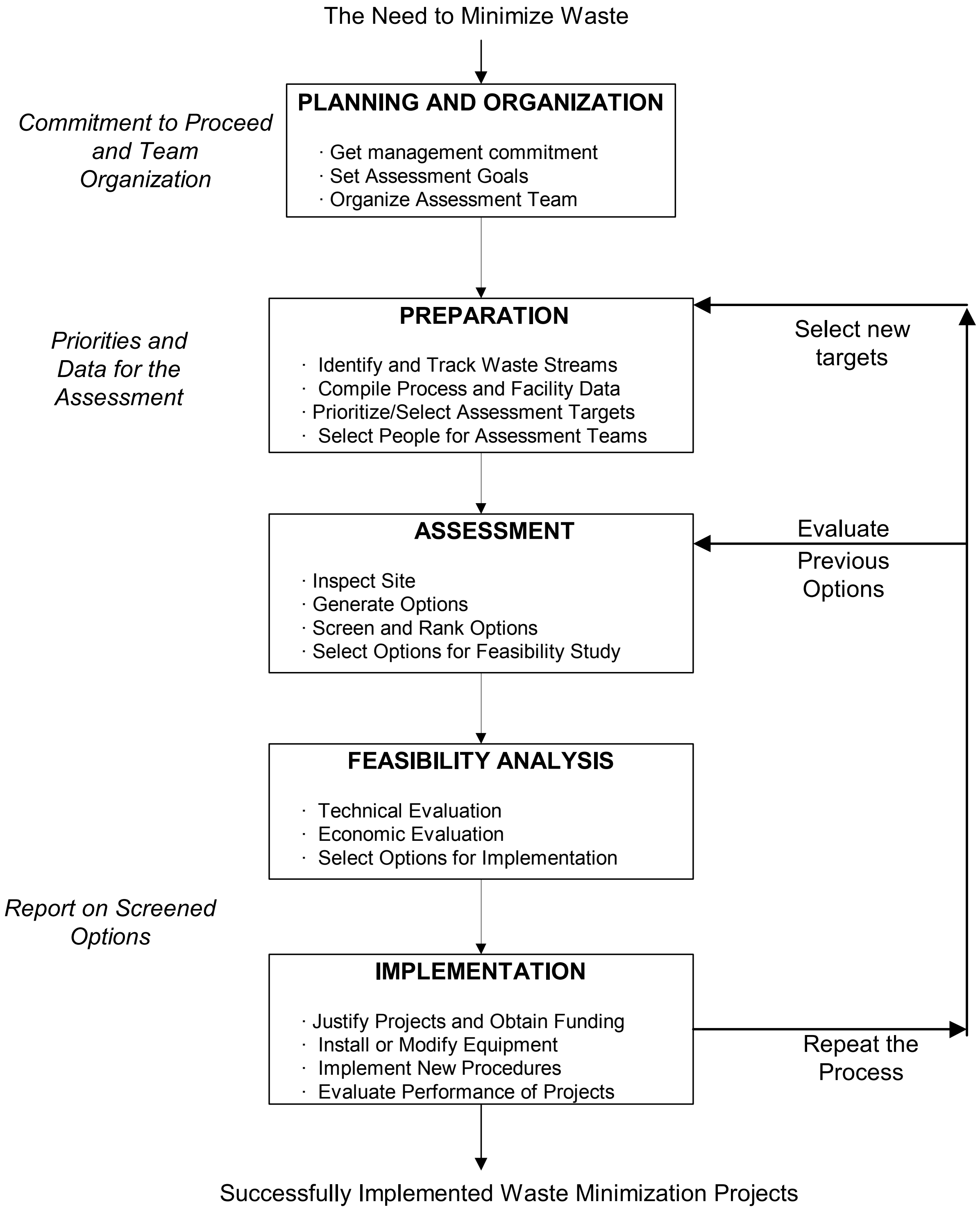


Figure 1. PPOA Process Diagram

Alternatives were identified through discussion and brainstorming with key personnel and were then screened based upon feasibility and practicality. Finally, a cost-benefit analysis was performed on the selected alternatives to determine the costs and return on investment (ROI) for implementation.

2. Facility Description

Organization 1700 is located at SNL/NM and for the purposes of this PPOA is concentrated at the Microelectronic Development Laboratory (MDL) within the Microsystems and Engineering Sciences Applications (MESA) Complex. Sandia is a national security laboratory operated for the U.S. Department of Energy (DOE) by the Sandia Corporation, 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.

Sandia's Microelectronic Development Laboratory

The Microelectronics Development Laboratory (MDL) was built in 1988 as a world-class facility dedicated to the advancement of microelectronic research, development, and application initiatives of strategic interest to the United States of America and the DOE. There is over 180,000 square feet of laboratory space consisting of a diverse and complete tool set that supports microelectronics initiatives in failure analysis, reliability, test, modeling and simulation, advanced packaging, radiation hardness assurance, device design, and silicon device fabrication.

Wafer Fabrication Clean Room

At the core of the MDL is a 30,000 square foot, state-of-the-art wafer fabrication clean room. This clean room is constructed on a laminar flow modular unit design consisting of 22 separate clean room bays integrated as a single wafer processing facility providing over 12,000 square feet of Class 1 (less than 1 particle larger than 0.5 microns in size per cubic foot of air) fabrication space. Each clean room bay is supported by an independent air handling and purification system allowing for maximum flexibility in the types of projects supported within the facility. The MDL wafer fabrication tool set includes semiconductor wafer fabrication equipment supporting full flow Complementary Metal-Oxide Semiconductor (CMOS) integrated circuit technologies on 6″ wafers. Lithography steppers of 'G' line, 'I' line, and Deep Ultraviolet (DUV) technology support minimum device feature sizes of 1.25 micron, 0.5 micron, and 0.35µm respectively. Three to four levels of metal and corresponding dielectric isolation are planarized via a state-of-the-art chemical mechanical polishing (CMP) capability.

Silicon Based Technologies

Technologies supported by the MDL wafer fabrication are silicon based and focused towards Sandia National Laboratories' mission as the steward of the nation's nuclear weapons stockpile. The center of this focus is the development and application of radiation hardened CMOS integrated circuit technologies capable of realizing digital, analog, mixed-mode, and nonvolatile memory circuits. In addition, the MDL wafer fabrication is the world's premier R&D source of surface micromachining technology and the integration of that technology with CMOS and Integrated Micro-Electro-Mechanical Systems (IMEMS).

Capabilities

The capabilities of the MDL wafer fabrication technologies and equipment set are leveraged to support partnerships with industry, academia, and other government agencies. Characteristic activities include benchmarking of advanced semiconductor process tools, technology development and transfer for commercial and government application, and post-doctorate research in semiconductor process and technology.

Professional Staff

- The MDL's 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.

MDL Process Areas

CMP, CVD, Diffusion, Wet Process, Photolithography, Metallization, Dry Etch, Implant, and Micro-Electro-Mechanical Systems (MEMS).

3. Waste Streams

At SNL/NM, the two most costly and frequently generated wastes are known as “hazardous” and “chemical” wastes. For the purposes of this report, these types of waste will be referred to collectively as hazardous waste. These wastes are tracked via 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 will be 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 Organization 1700 are considered hazardous. The primary hazardous waste streams are depicted in the pie chart in Figure 2. The waste streams of Organization 1700 cost nearly $300,000 a year for disposal. Waste generated from Organization 1700 accounts for approximately 10 percent of the site’s total waste and about 18 percent of the total disposal costs. Beginning on September 15, 2006 the chargeback system for disposal of hazardous chemicals was changed. As of this date, all hazardous waste became subject to a $28 per kilogram charge. This new chargeback program will increase the cost of disposal by nearly 40% in Org. 1700 See Figure 4 and Figure 5. For these reasons, a PPOA was recommended for Organization 1700.

3.1 Organization 1700 Processes and Wastes

Figure 2 lists major waste streams generated from Org.1700 and illustrates the comparative weight of each waste stream. The largest waste streams generated in Org. 1700 are from the wet and photo processes area located in Building 858. This PPOA will consider potential waste reduction ideas for each of these waste streams. Figure 3 shows the average annual quantities in kilograms of these top three waste streams. These top 3 waste streams comprise of nearly 41% of the hazardous and chemical waste generated in Org. 1700.

The top three waste streams are:

- PRS-1000 Photoresist Stripper
- EKC 265 Post Etch Residue Remover
- Hydrofluoric Contaminated Lab Trash

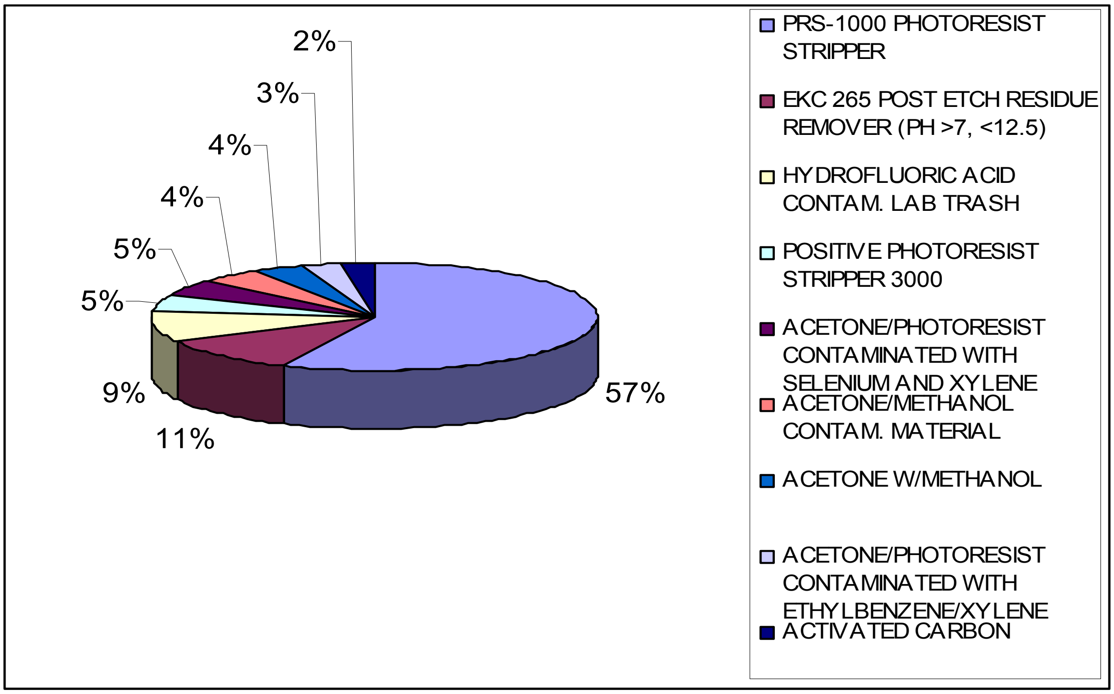


Figure 2. Percentage by Weight (kg) of the Top 9 Waste Streams of Organization 1700 (July 2005 – June 2006)

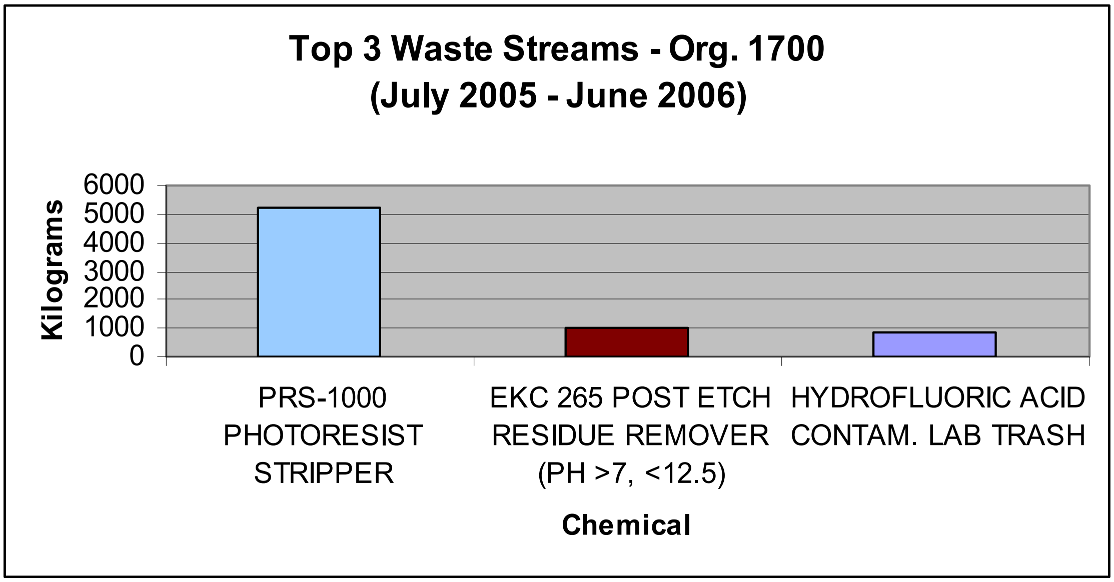


Figure 3. Top 3 Waste Streams of Org. 1700 – July 2005 – June 2006 (41% of Org.1700 Waste Streams)

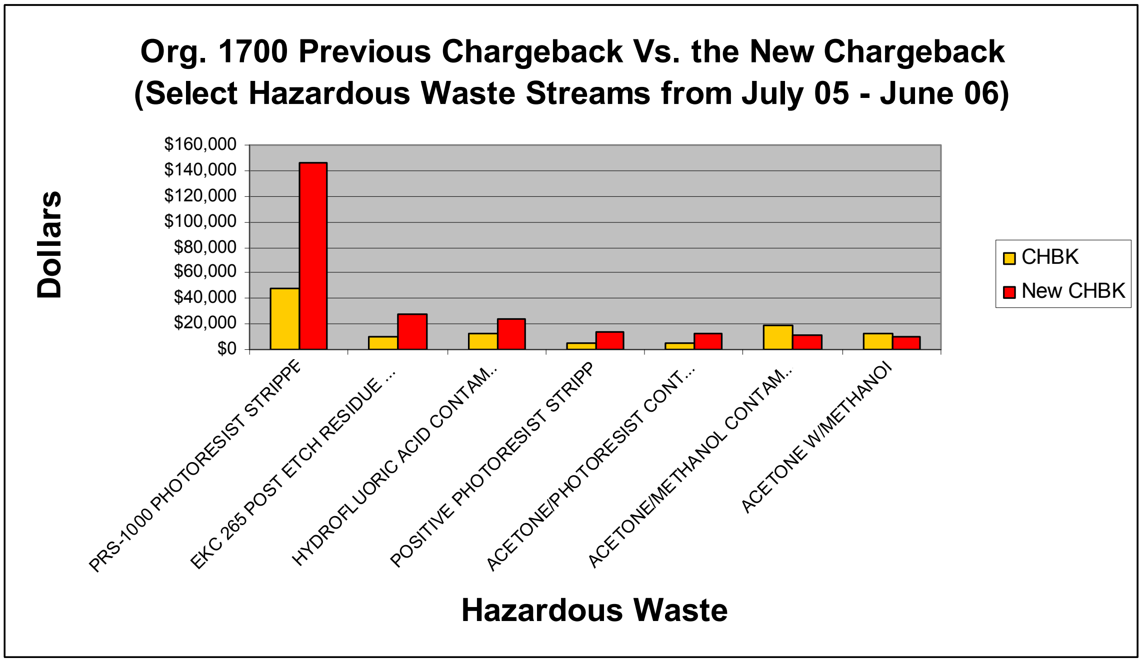


Figure 4. Example of Org. 1700 Chargeback Prior to September 15, 2006 Compared to the New Chargeback Costs for Select Hazardous Waste Streams

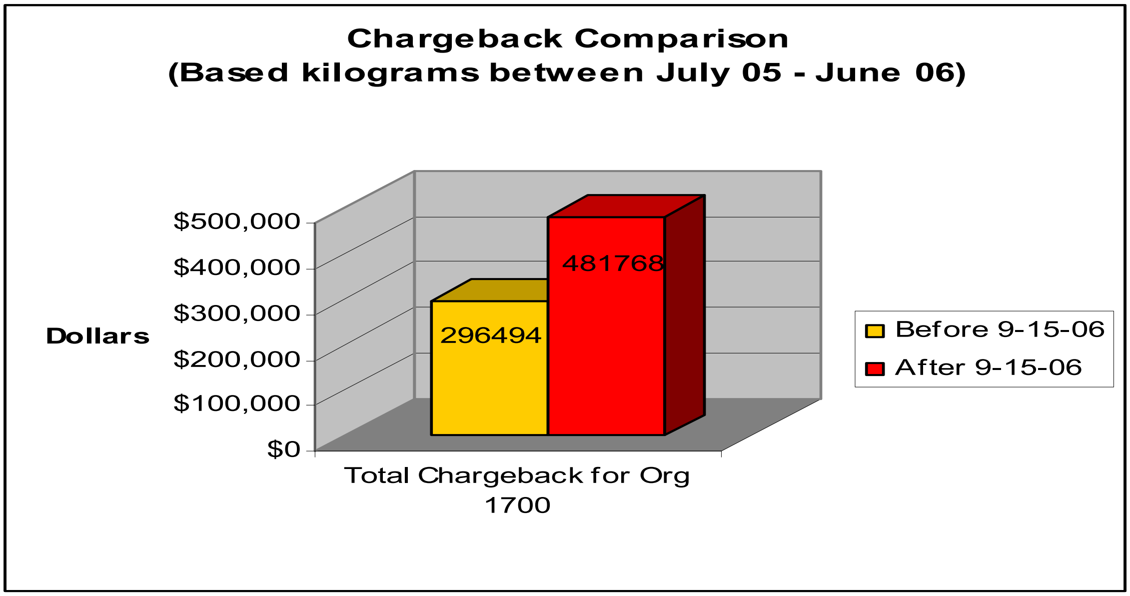


Figure 5. Total Cost of Chargeback if New Chargeback Rate Were to be Applied to July 05–June06 Kilograms of Hazardous Waste for Org. 1700.

3.2 Overview of the CMOS IC Process Flow

The MDL-MESA uses a Complementary Metal-Oxide-Semiconductor (CMOS) integrated circuit (IC) process which consists of a sequence of operations which varies depending on the respective design. A number of the process steps and operations are executed repetitively in the production of the CMOS IC. The process flow at MDL-MESA can be introduced by understanding these standard and repetitive process steps and their descriptions (Figure 6).

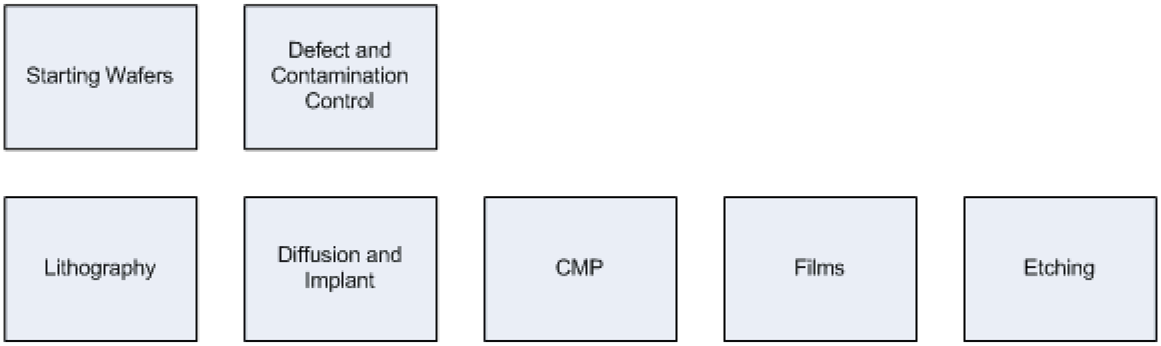


Figure 6. Generic Integrated Circuit (IC) Production Steps

An overview of the 7 generic process steps is as follows:

Starting Wafers

Typical wafers are made of extremely pure silicon. A silicon wafer starts off being about 0.75 mm thick. They are received into the process after being polished to ensure a very flat surface.

Defect and Contamination Control

It is absolutely critical that wafers received into the process are free of defects and contamination. There are many sources of particles and contaminants such as air, water, equipment, and people. Defects and contamination can lead to yield and early-life reliability problems. Clean rooms (Example: Class 1 clean room = 1 particle per square foot of air) offer a high efficiency filtered environment, proper personal protective equipment (PPE), wafer handling devices, and some process equipment that helps eliminate the possibility of contamination and defects of incoming wafers.

Lithography

Lithography is the most important part of processing IC's. Normally, a designer makes a computer aided design (CAD) which is then transferred to a transparent plate leaving a photo mask of the design. A wafer is then coated with a photosensitive resist which hardens with light. The photo masked plate now with opaque areas printed on it, is placed between a source of illumination and the wafer, selectively exposing parts of the substrate to light. Then the photosensitive resist or photoresist is developed and hard baked. The areas of the wafer that were not hardened, because of the photo mask, are then removed chemically leaving the desired feature on the wafer. This step can be repeated (cycled through) over 20 times depending on the number of desired layers and circuit design.

Diffusion and Implant

Diffusion and ion implantation is used in IC processing extensively. This is a materials engineering process by which ions of a material can be implanted into another solid. This changes the physical properties of the solid. Doping is one such application of ion implantation. When implanted the dopant atom creates a charge carrier in the semiconductor. This ion implantation can modify the conductivity of the nearby semiconductor.

CMP

Chemical-Mechanical Polishing or Chemical-Mechanical Planarization, commonly known as CMP, makes the semiconductor surface approximately flat. This process uses abrasive slurry with a polishing pad and a wafer retaining ring. A dynamic polishing head is then applied to the pad, ring, and wafer to remove irregular topography, make the wafer flat, and to set the wafer up for additional circuit elements.

Films

Films encompass the deposition process. Deposition is any process that grows, coats, or otherwise transfers a material to a wafer. There are several technologies used to perform these activities. The two most common are Chemical Vapor Deposition (CVD) and Physical Vapor Deposition (PVD). CVD is often used to produce thin films such as poly-silicon, silicon dioxide, and silicon nitride. PVD is a process to apply materials, such as thin films to a wafer, using mechanical and thermodynamic means.

Etching

Etching is used to chemically remove layers from the surface of a wafer. During many etch steps; the wafer is protected by a masking material which resists the chemical etching capabilities. Wet etching, with wet chemistries, is typically used with deeper and wider features. Conversely, cry etching, with chemical vapors, is superior for smaller features but acts well with deeper and wider features as well.

The result of these standard steps and their respective processes is the formation of many integrated circuits side-by-side on the original wafer. These wafer's devices are then tested. Once tested the wafer is scored and then broken into chips. Good chips go to be packaged.

3.3 MDL-MESA CMOS IC Production Flow

The MDL-MESA CMOS IC production flow, like most semiconductor processes, has a Front-End-of-Line (FEOL) and a Back-End-of-Line (BEOL) process.

The FEOL refers to the first portion of the IC fabrication where the individual transistors and other devices are patterned in the semiconductor. Most steps are covered in the FEOL (Figure 7) except for the deposition of metal layers (which occurs in the BEOL process). **Attachment #1** contains detailed information on the MDL MESA FEOL process steps.

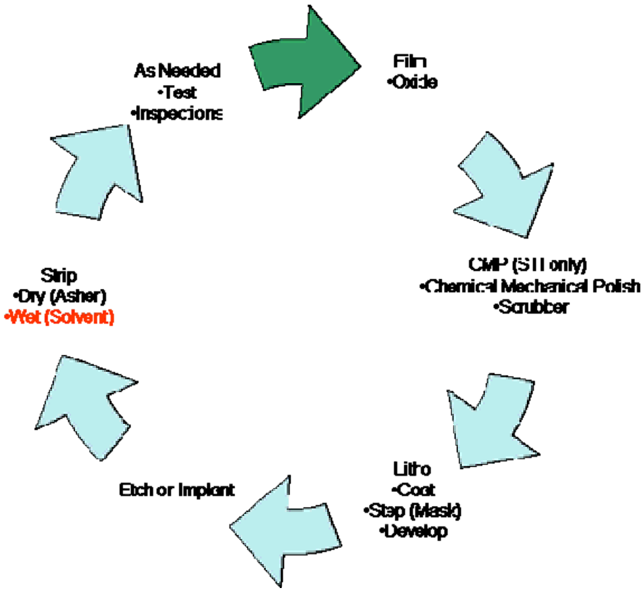


Figure 7. Current FEOL Process Flow.
Green arrow indicates Step 1. PRS1000 is Used as Wet Solvent

The BEOL are the steps that involve the creation of the metal interconnecting wires which are isolated by the insulating dielectrics such as silicon dioxide (Figure 8). **Attachment #2** contains detailed information on the MDL MESA BEOL process steps.

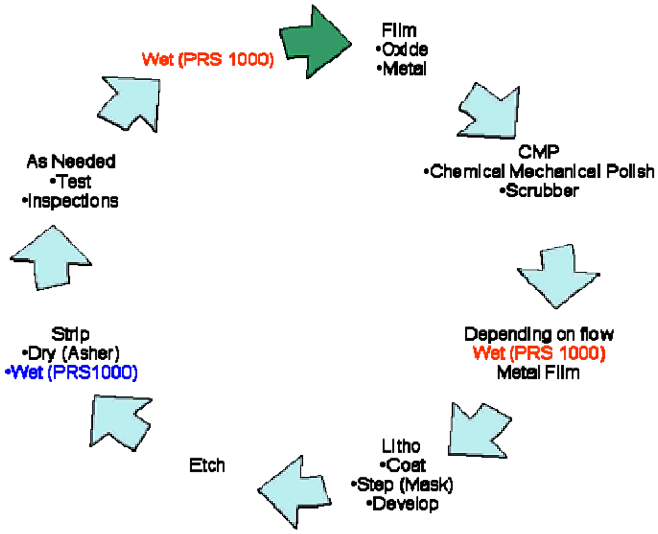


Figure 8. Current BEOL Process Flow. Green arrow indicates Step 1

3.4 Priority Processes and Waste Streams

Initially, the largest three hazardous waste streams were evaluated. When reviewing all of the process waste data for Organization 1700 over a period of a year, the top three waste streams stood apart from the rest. Of the nine largest waste streams, the top three comprised of 77% of the total waste generated at Organization 1700. These were the PRS-1000 Photoresist Stripper, the EKC 265 Post Etch Residue Remover, and Hydrofluoric Contaminated Lab Trash Waste Stream. A review of these process steps provided needed information for the Pollution Prevention Ideas and Opportunities section of this report.

3.4.1 PRS-1000 Photoresist Stripper and EKC 265 Post Etch Residue Remover Process and Waste Stream

PRS-1000 and EKC 265 are used for resist and/or polymer removal from wafers. These processes are located in the clean room photo-process area of MDL-MESA. The automated recipe for stripping the resist/polymer from the wafers has been optimized to use chemicals for a second pass when possible. Cassettes from 1 to 25 wafers can be processed at a time. The system can also handle cassettes of 50 wafers at any one time.

The PRS-1000 Photoresist Stripper waste stream is by far the largest hazardous waste stream within Org. 1700. Approximately, 430 kilograms per month or nearly 5160 kilograms per year are disposed of as hazardous waste. The PRS-1000 Photoresist Stripper, though mainly consisting of water, contains some hazardous solvent components such as1-methyl-2-pyrrolidinone and tetrahydrothiophene-1, 1 dioxide. The combination of these two compounds and others creates an effective solvent polymer stripper. Furthermore, solvent components such as these requires proper hazardous waste disposal and can’t be sent to municipal sewer. During the calendar years of 2004 and 2005, PRS-1000 Photoresist Stripper Waste was recycled through the Stripper Recovery Program at Mallinckrodt Baker, the manufacturer of the chemistry. This program abruptly ended in late 2005.

Both the PRS-1000 and EKC 265 are used in the same production tool but are dispensed and used separately based on the process step. The chemistries are plumbed to the same drain line but are segregated into separate drums.

The PRS-1000 Photoresist Stripper is commonly used throughout the repetitive CMOS IC process. Currently, PRS-1000 is used in both the FEOL and BEOL processes (Figure 7 and Figure 8) at the MESA MDL. In the FEOL, PRS-1000 is used after ever Asher step (dry resist strip). In the BEOL, PRS-1000 is used as a polymer clean prior to CMP oxide clean, after the out Asher, before every metal/oxide deposition, and after every CMP metal scrub (See Attachment #1 and #2)

3.4.2 Hydrofluoric (HF) Contaminated Lab Trash Waste Stream

This waste stream is comprised of all acid contaminated wipes and PPE used in the clean room. Normally, contaminated PPE and wipes are used through the shift and then discarded. At times, PPE is used when the process step is complete and then discarded. All acid materials disposed of in the clean room are placed in the appropriately labeled hazardous waste containers.

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 ideas within the realm of their expertise. The ideas identified and evaluated are summarized below: I can't see the process diagrams. Maybe they clarify. That is another issue. If the diagrams are saved as Visio figures, a lot of people can't read them. Better to paste them as a metafile.

- Idea 1: Minimize waste of PRS-1000 Photoresist stripper by,
  - Recycling the waste stream
  - Optimizing the process
- Idea 2: Minimize waste of EKC Post Etch residue remover by
  - Recycling the waste stream
  - Optimizing the process
- Idea 3: Minimize waste of HF acid contaminated material by,
  - Segregation and decontamination of other acid type materials in the waste stream
- Idea 4: Recycle wafer containers or "coin boxes" by,
  - Creating a recycling stream for the plastic type
- Idea 5: Recycle Tyvek suits by,
  - Adding to current recycle stream at Sandia
- Idea 6: Reduce water use at rinse baths by,
  - Optimizing water rinse process
- Idea 7: Reduce or eliminate acetone wipes waste stream by,
  - Updating procedure and providing training

Ideas 2 and 5 were rejected for the following reasons:

- Idea 2: The process that uses EKC Post Etch Residue Remover has been optimized and there is no opportunity to minimize this waste stream. EKC Post Etch Residue Remover is needed for particular polymer removals.
- Idea 5: There are too few Tyvek suits worn by construction. Tyvek suits are worn on occasion for construction work around the building. The use of these suits is intermittent and the quantity of suits is minimal. At this time the team doesn't feel that it is feasible to implement a recycling process

5. Description and Analysis of P2 Opportunities

5.1 Opportunity 1: Minimize Waste of PRS-1000 Photoresist Stripper

There are three options to minimize the waste of the PRS-1000 Photoresist Stripper. Each option can be performed separately or combined. Implementation of the titration unit option is a priority compared to the other options. All process changes require rigorous and often time consuming qualifications and experimentation which would be the case for FEOL and BEOL modifications. A staggered approach to full implementation may be the preferred approach to incorporate all options.

5.1.1 PRS-1000 Photoresist Stripper Bath Life Extension Option

The introduction of a commercially available titration unit for solvents to the current PRS-1000 Photoresist Stripper process would extend the PRS-1000 bath life by at least double. The main reason PRS-1000 has a short life as a photoresist stripper is that the DI water is removed from the chemistry by evaporation during the process (process runs at 80°C). When the PRS-1000 solvent loses DI water the concentration exceeds what is required and could affect the resulting wafer product(s). As shown in Figure 9, the titration unit takes a sample of the PRS-1000 recirculation tank, makes a determination if DI water is needed and adds DI water as appropriate. This modified process could reuse the PRS-1000 Photoresist stripper 2 to 4 times (determined by experimentation) or a minimum of a 50% reduction in the use of the chemistry. See Attachment 3 for cost estimates and assumptions.

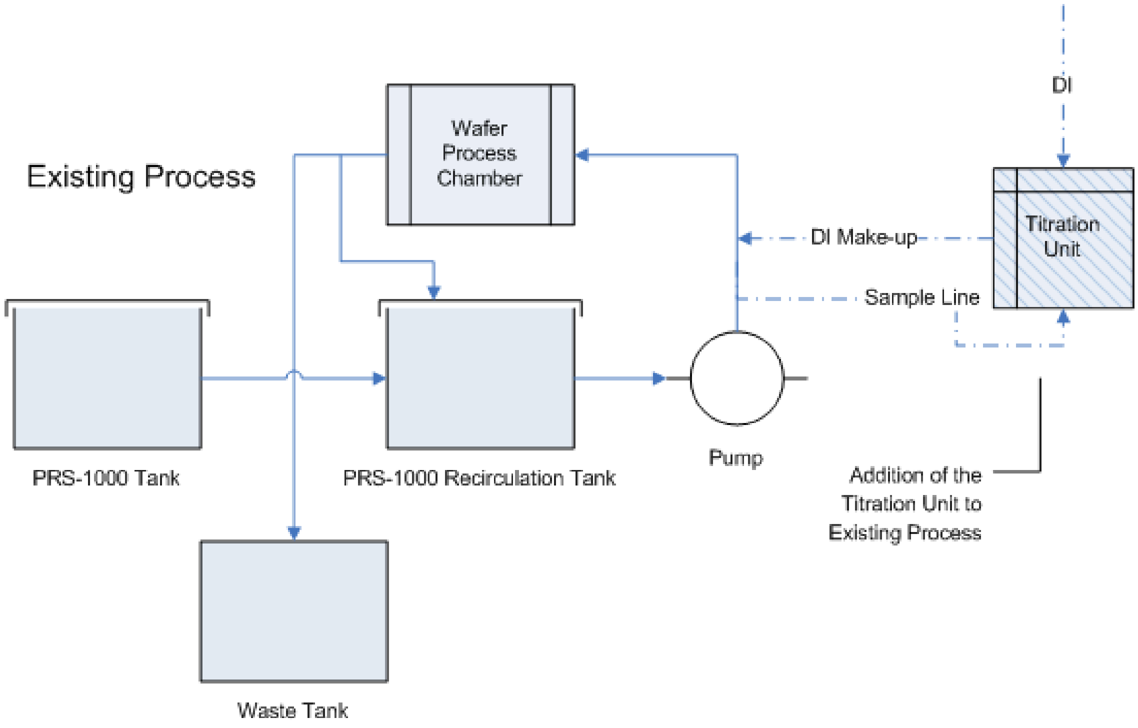


Figure 9. Modified PRS-1000 Photoresist Process Which Incorporates a Solvent Titration System

5.1.2 BEOL Process Step Reduction Option

The BEOL process currently uses PRS-1000 Photoresist Stripper extensively through its processes. PRS-1000 Photoresist Stripper is a polymer cleaner and is currently used before metal/oxide deposition. Prior to the metal/oxide deposition step the wafer has already been cleaned at the prior to the Asher. Also, PRS-1000 Photoresist Stripper is used post-CMP. CMP has removed any existing polymer on the wafers that could be removed. Therefore, there is no need for PRS-1000 at post-CMP. Removing these unneeded steps would reduce the use of PRS-1000 Photoresist Stripper by approximately 50%. See Attachment 1 and 2 for process flow changes. See Attachment 3 for cost estimates and assumptions.

5.1.3 FEOL PRS-1000 Photoresist Stripper Substitution Option

PRS-1000 Photoresist Stripper is being used in the FEOL. PRS-1000 is not recommended for FEOL processes because of high metals. Since the same tool is used for BEOL processes where many metal processes exist there is a potential of cross-contamination between the two processes. Metal contamination can significantly affect process steps up stream reducing production yields. There is a more effective chemical solution for the post-Asher step, called Piranha (sulfuric acid and peroxide). By substituting PRS-1000 with the Piranha, the overall use of PRS-1000 can be reduced by 20%. Use of the Piranha solution will not only eliminate the use of PRS-1000 Photoresist Stripper and the sulfuric-nitric step that follows (see Attachment #2), but it can be sent to the Acid Waste Neutralization System (AWNS), where it is neutralized and sent to the municipal sewer. See Attachment 3 for cost estimates and assumptions.

5.2 Opportunity 2: 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 states that after each process, the wet benches should be wiped down. The wipes should then be discarded in the hazardous waste container. Also, at the end of each process and shift, gloves are to be removed and placed in the hazardous waste container. At least 50% of this hazardous waste stream is comprised of gloves. Instead of throwing away the gloves in the hazardous waste container, they can be rinsed in the glove rinse baths and then thrown into the solid waste stream (this will require a study to determine how much chemical resides on the gloves before and after the process). Updates to procedures and training are all that are required to reduce this waste stream by 50%. This opportunity will save approximately $11,760 per year in disposal costs and reduce approximately 420 kilograms of waste.

5.3 Opportunity 3: Reduce or Eliminate Acetone Wipes

Approximately 400 kg a year of acetone wipes are used to wipe down equipment in the MDL. The current procedure is to dispose of these wipes as hazardous waste. Most of these wipes can be thrown into solid waste if the wipes are used until dry. This simple procedure modification and training would eliminate this hazardous waste stream altogether. Elimination of this waste stream will save approximately $11,200 per year in disposal costs.

5.4 Opportunity 4: Reduce Water Use at Rinse Baths

By optimizing rinse bath recipes to approach industry standards approximately 30% of the DI water can be saved from going to drain. Currently, rinse baths have excessive water dumping. For example, the sulfuric-nitric bath dumps rinse water 10 times (3-5 Gal. / rinse bath) for each processed wafer cassette. Industry standards have proven that 4-5 dumps is sufficient. Table 1 shows how much the top 5 rinse water baths use and the result of their reduction. The final water savings quantity of 110684 gallons-saved would be doubled or tripled if the same rinse water optimization was applied to all rinse baths in the wet processing area.

Table 1
Represents the Top 5 Rinse Water Using
Baths and Potential Rinse Water Savings

Tool	Lots 2006	QDR cycles	Vol L	Rinse DI use L	Rinse DI use gal	% Reduced	Water Savings Gal
WB-11	2831	10	10	283100	74809.1	30	22442.7
WB-04	6031	10	10	603100	159369.0	30	47810.7
WB-17	2750	10	10	275000	72668.7	30	21800.6
WB-14	1217	10	10	121700	32159.2	30	9647.8
WB-18	1133	10	10	113300	29939.5	30	8981.8
Totals					368945.4		110683.6

5.4.1 Weep DI Reduction

By optimizing the Trickle Bypass flow (weeping) to prevent bacterial build-up to industrial standards, 50% of the waste rinse bath water could be reduced. The final water gallons saved amount of 173612 (Table 2) would be doubled or tripled if this optimization was applied to all rinse baths in the wet processing area.

Table 2
Represents the Top 5 Water Using
Baths and their Potential Weep Water Savings

Tool	Flow ML/min	L used/ year	Gals used/Yr	% Reduction	Gals Saved
WB-11	500	262800	69444.8	50	34722.4
WB-04	500	262800	69444.8	50	34722.4
WB-17	500	262800	69444.8	50	34722.4
WB-14	500	262800	69444.8	50	34722.4
WB-18	500	262800	69444.8	50	34722.4
Total			347224.1		173612.0

5.5 Opportunity 5: Recycle Wafer Containers or “Coin Boxes”

Incoming wafer containers or “coin boxes” can be recycled through the Solid Waste Transfer Facility (SWTF). This process has been implemented. This new process has eliminated 100-200 wafer containers a month from going into the landfill.

6. Conclusion

The five opportunities identified in this report can significantly reduce the cost and waste generation rates in Organization 1700. Given the significant potential for ROI on the equipment investments, it is recommended that the opportunities be implemented. The primary objective was to reduce the largest waste stream in Organization 1700 which is the PRS-1000 Photoresist Stripper. The three options in Opportunity 1 suggested can be implemented independently of each other or combined for a significant reduction in waste. Figure 10 and 11 provide the significant waste reduction potential.

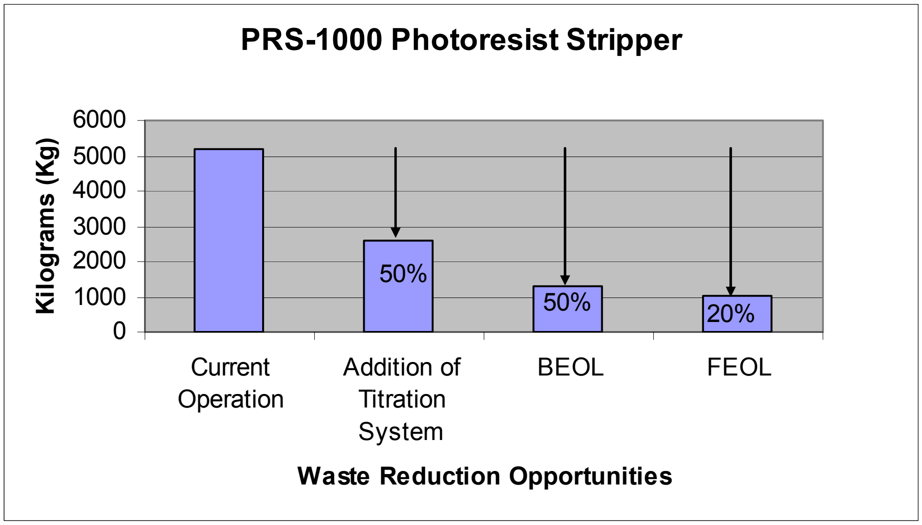


Figure 10. Kilograms of PRS-1000 Photoresist Stripper Reduced by Implementing Some or All Options in Opportunity 1

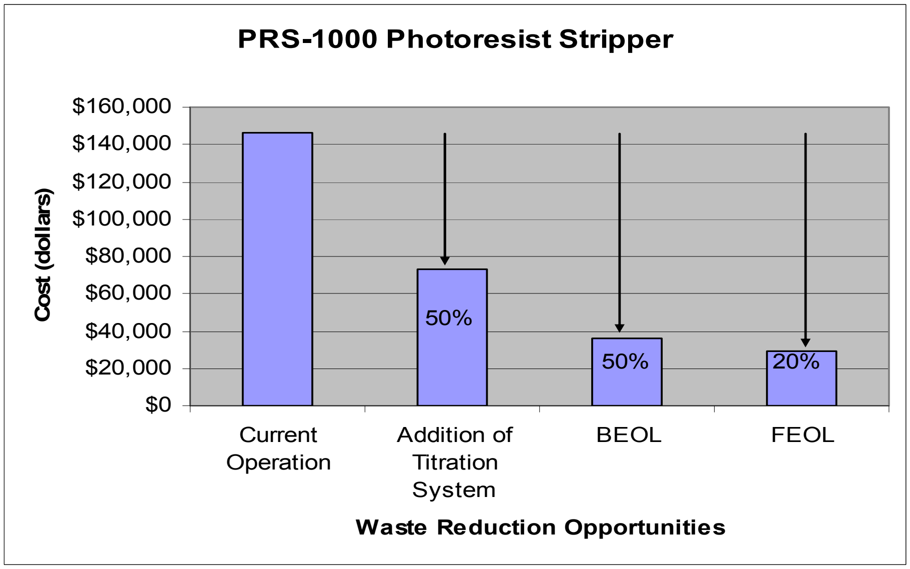


Figure 11: Disposal Costs Reduced by Implemented Some or All Options in Opportunity 1

Opportunity 1 (Option 1) will require the implementation of a titration unit that will cost approximately $140,000 while Option 2 and 3 will require process modifications and qualifications. Process modifications and qualifications normally require 6 months to a year to implement.

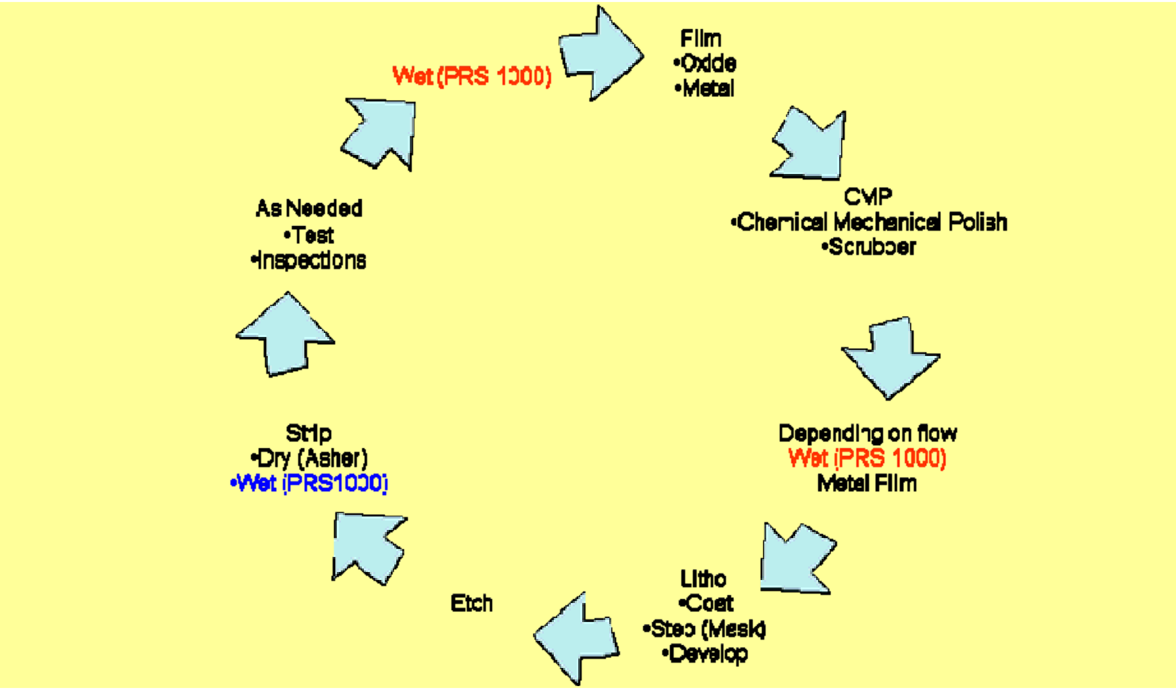
Opportunities 2 & 3 are simple to implement. All they will require are procedural updates and minimal training. It is important that these processes are evaluated by ES&H. Opportunity 2 (rinsing gloves and disposed of as solid waste) needs to be reviewed and it must be documented as a non-treatment process. If both were implemented, approximately $23,000 per year would be saved in disposal costs.

Opportunity 4 is no less important than hazardous waste reduction. Water is a precious resource and SNL/NM has already exceeded its Site Wide Environmental Impact (SWEIS) cap. The MDL uses nearly 15% of the water and is the largest user at SNL/NM. The two options in Opportunity 4 are easy to implement and based on industry standards will have absolutely no effect on the products.

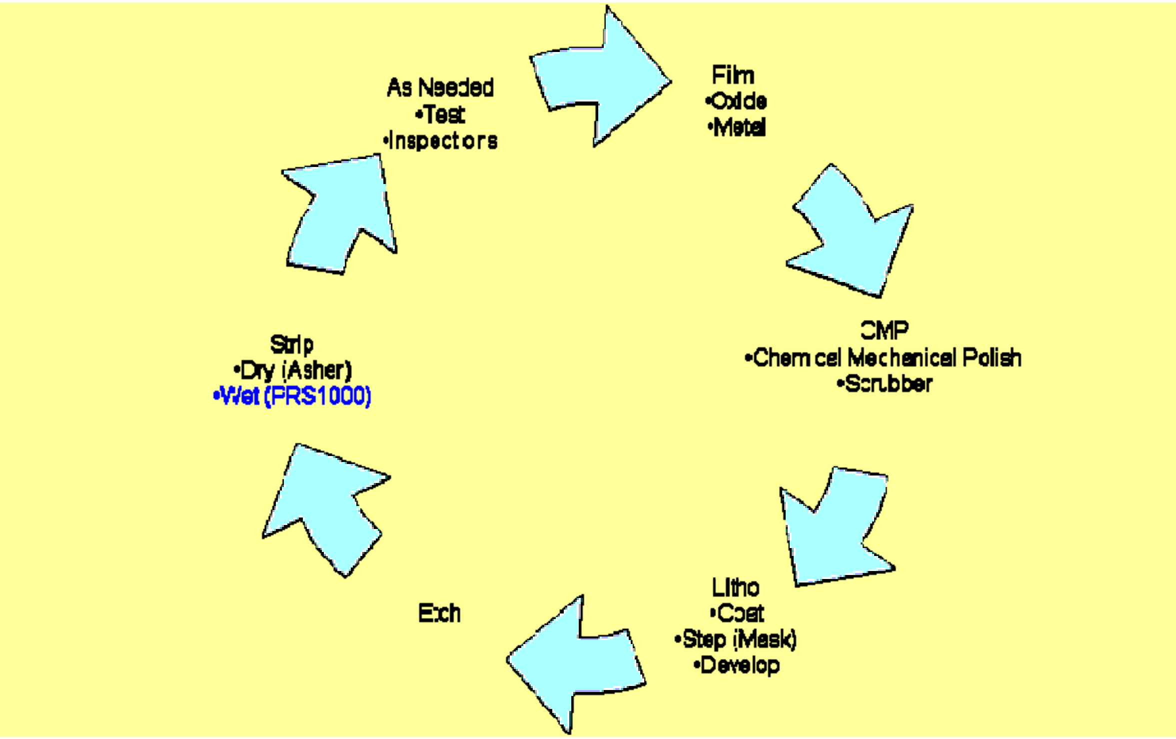
Opportunity 5 has already been implemented. Approximately 100-200 wafer containers are recycled as HDPE #5 plastic at the SWTF at SNL/NM.

In total, if all opportunities within this PPOA were implemented, hazardous waste would be reduced by approximately 5000 kilograms and water use would be reduced by at least 500,000 gallons per year.

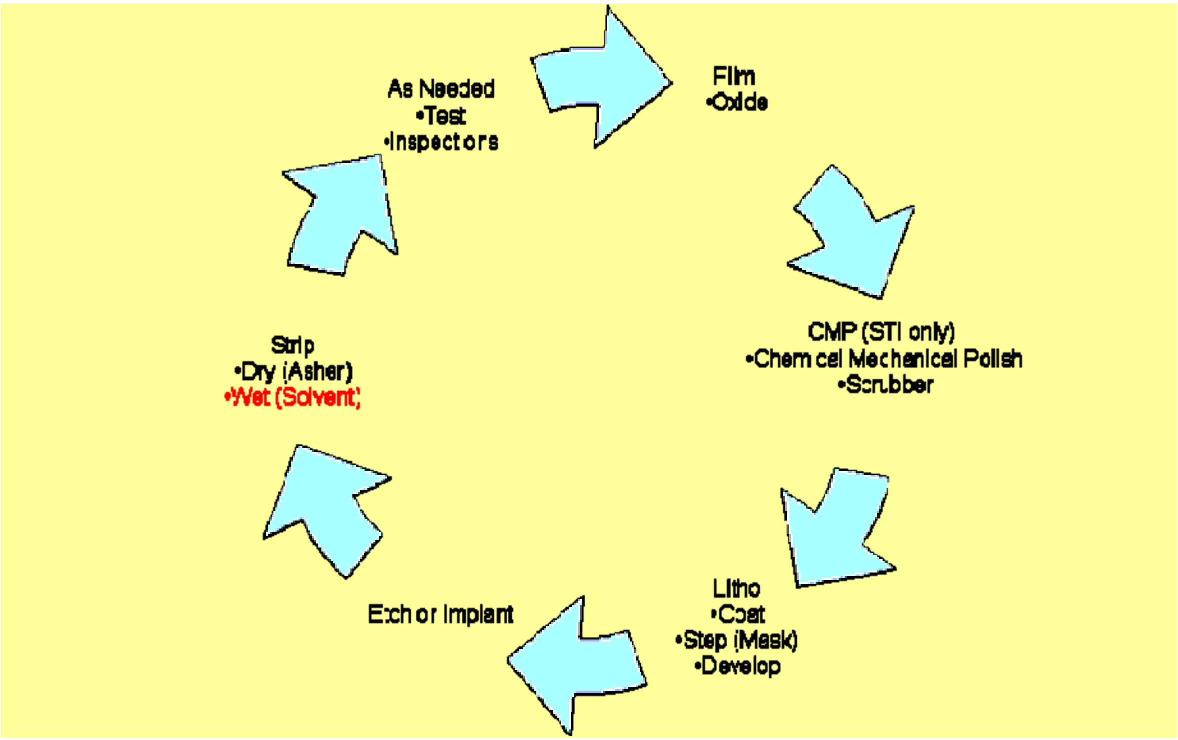
Attachment 1
BEOL & FEOL Standard and Recommended Process Flows (Graphical)



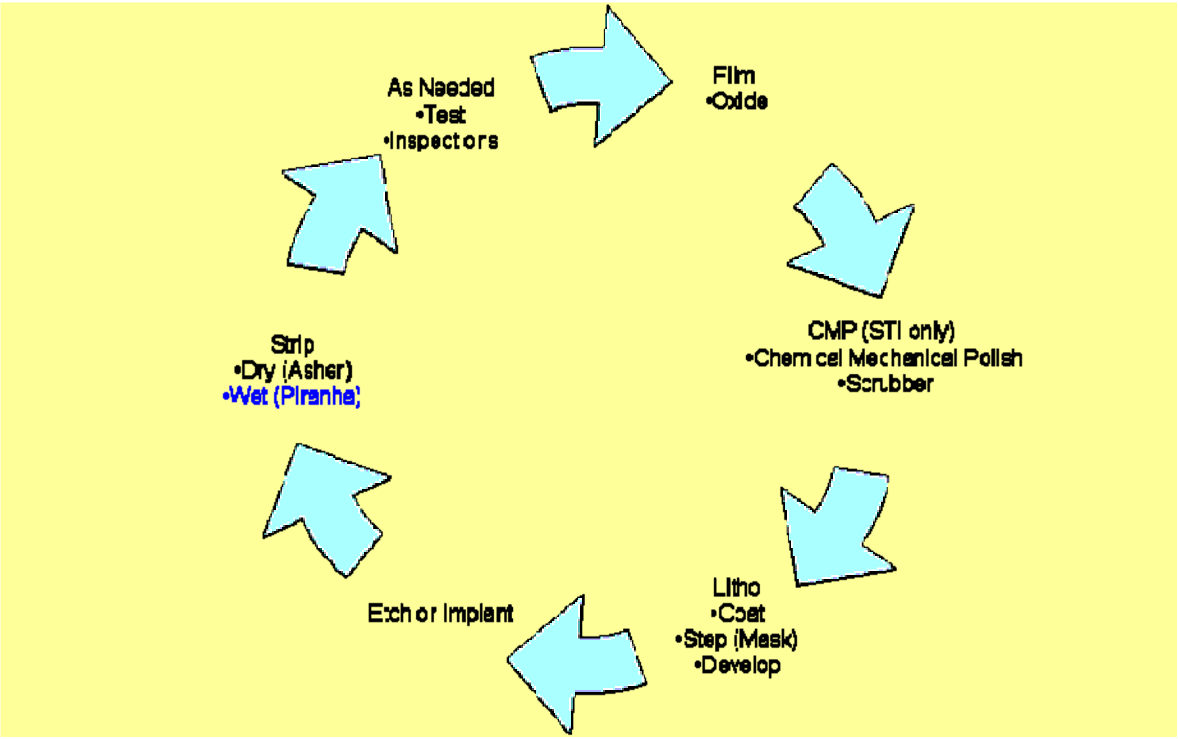
BEOL Standard Process. The Film Step is the first step.



BEOL Simplified Process. The Film step is the first step.

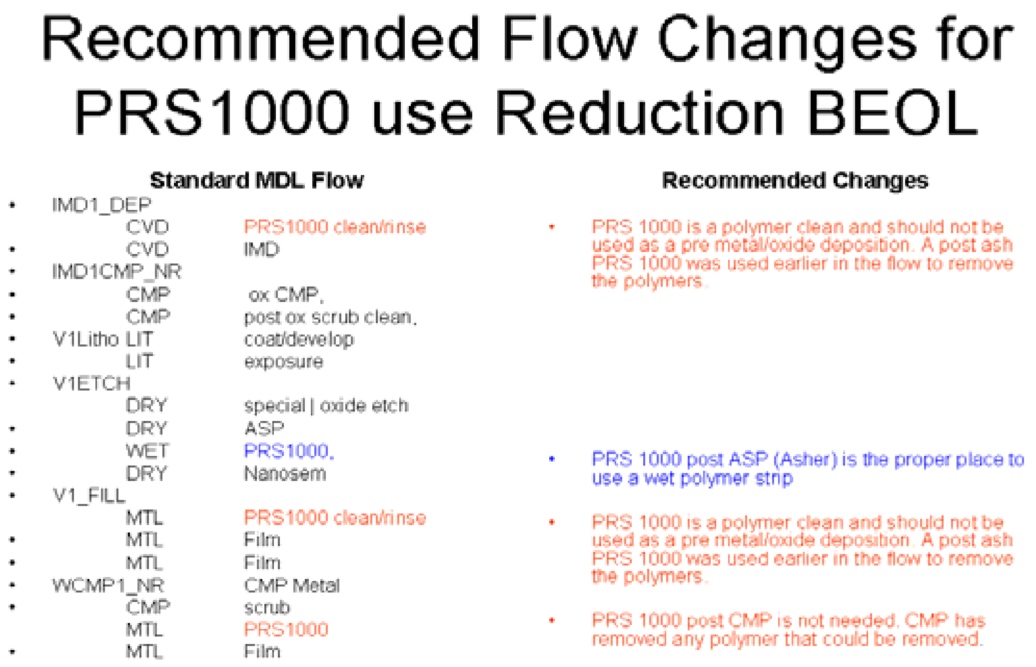


FEOL Standard Process. The Film step is the first step.



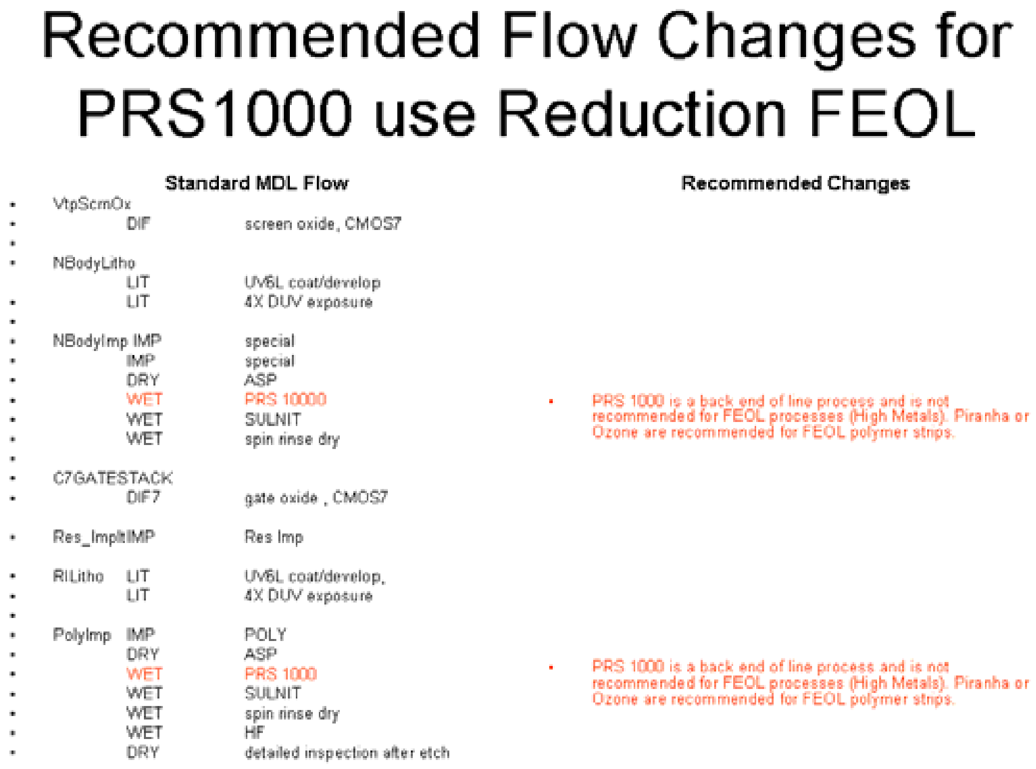
FEOL Simplified Process. The Film step is the first step.

Attachment 2
BEOL & FEOL Process Steps with Recommended Changes



Recommended Flow Changes for PRS1000 use Reduction BEOL

Standard MDL Flow			Recommended Changes
IMD1_DEP			
	CVD	PRS1000 clean/rinse	PRS 1000 is a polymer clean and should not be used as a pre metal/oxide deposition. A post ash PRS 1000 was used earlier in the flow to remove the polymers.
	CVD	IMD	
IMD1CMP_NR			
	CMP	ox CMP,	
	CMP	post ox scrub clean,	
V1Litho	LIT	coat/develop	
	LIT	exposure	
V1ETCH			
	DRY	special | oxide etch	
	DRY	ASP	
	WET	PRS1000,	PRS 1000 post ASP (Asher) is the proper place to use a wet polymer strip
	DRY	Nanosem	
V1_FILL			
	MTL	PRS1000 clean/rinse	PRS 1000 is a polymer clean and should not be used as a pre metal/oxide deposition. A post ash PRS 1000 was used earlier in the flow to remove the polymers.
	MTL	Film	
	MTL	Film	
WCMP1_NR		CMP Metal	
	CMP	scrub	
	MTL	PRS1000	PRS 1000 post CMP is not needed. CMP has removed any polymer that could be removed.
	MTL	Film	



Recommended Flow Changes for PRS1000 use Reduction FEOL

Standard MDL Flow			Recommended Changes
VtpScrnOx			
	DIF	screen oxide, CMOS7	
NBodyLitho			
	LIT	UV6L coat/develop	
	LIT	4X DUV exposure	
NBodyImp	IMP	special	
	IMP	special	
	DRY	ASP	
	WET	PRS 10000	PRS 1000 is a back end of line process and is not recommended for FEOL processes (High Metals). Piranha or Ozone are recommended for FEOL polymer strips.
	WET	SULNIT	
	WET	spin rinse dry	
C7GATESTACK			
	DIF7	gate oxide , CMOS7	
Res_Implt	IMP	Res Imp	
RILitho	LIT	UV6L coat/develop,	
	LIT	4X DUV exposure	
PolyImp	IMP	POLY	
	DRY	ASP	
	WET	PRS 1000	PRS 1000 is a back end of line process and is not recommended for FEOL processes (High Metals). Piranha or Ozone are recommended for FEOL polymer strips.
	WET	SULNIT	
	WET	spin rinse dry	
	WET	HF	
	DRY	detailed inspection after etch	

Attachment 3
Cost Estimates and Assumptions

PRS-1000 Titration Unit

Worksheet 3: Estimate Basis

ASSUMPTIONS FOR PRS-1000 TITRATION UNIT

The costing analysis uses the assumption that the titration unit will increase the life of the chemistry by 50%. It is assumed the qualification period will take 6 months to complete.

EXISTING TECHNOLOGY

The existing system consists of a PRS-1000 tank, a PRS-1000 Recirculation tank and the wafer process chamber. The procedure for the process is to load a cassette of wafers into the wafer process chamber and select the associated automated recipe. The wafers are then sprayed and spun for full coverage of the wafers with the PRS-1000 based on the selected recipe. PRS-1000 is released into the chamber at 80ºC during the process from the Recirculation tank. At this temperature, much of the DI water is evaporated from the chemistry and it is either disposed of to the Waste Tank or sent back to the Recirculation Tank. The process is regulated by a feed-and-bleed system to balance the concentration of PRS-1000 within the Recirculation Tank. Each cassette processed uses approximately 1.5 gallons of PRS-1000. The annual purchases of virgin PRS-1000 are approximately $18,000. The amount disposed of costs nearly a $146,000 a year.

PROPOSED P2 TECHNOLOGY

The proposed P2 technology is to add a titration unit to the existing system. The titration unit would be used to test the PRS-1000 concentration and replenish it with DI water when needed to compensate for evaporation. The result will require less PRS-1000 to be fed to the system because the existing PRS-1000 concentration will be more than adequate to extend the life of the chemistry by 2X.

INITIAL CAPITAL INVESTMENT

The initial capital investment is the purchase of a titration unit.

Titration Unit Cost: $110,000 (based on information from AMTI)
Materials: $10,000 for additional Dosing Control Module and sensor
Installation: $10,000
Qualification Costs: $10,000

COST SAVINGS, COST AVOIDANCE, AND RISK REDUCTION

Cost savings are based mainly on the reduction of waste generation. The purchasing of process chemicals was also reduced by approximately 50%.

Worksheet 1: Operating and Maintenance Annual Recurring Costs

Expense Cost Items	Before (B) Annual Costs		After (A) Annual Costs
Equipment			
Purchased Raw Materials and Supplies			
Process Operation Costs:	$18,000		$9,000
Utility Costs			
Labor Costs			
Routine Maintenance Costs for Processes			
Process Costs			
Other			
Subtotal	$18,000		$9,000
PPE and Related Health/Safety/Supply Costs			
Waste Management Costs:	145964		72982
Waste Container costs			
Treatment/Storage/Disposal Costs			
Inspection/Compliance Costs			
Subtotal	$145,964		$72,982
Recycling – Material Collection/Separation/Preparation Costs:			
Material and Supply Costs			
Operations and Maintenance Labor Costs			
Vendor Costs for Recycling			
Subtotal	$0		$0
Administrative/Other Costs			
Total Annual Cost:	$163,964		$81,982

Worksheet 2: Itemized Project Funding Requirements (One-Time Implementation Costs)

Category			Cost $
INITIAL CAPITAL INVESTMENT			
Design			
Purchase			$120,000
Installation			$10,000
Other Capital Investment (explain)			
Subtotal: Capital Investment = (C)			$130,000
INSTALLATION OPERATING EXPENSES			
Planning/Procedure Development			
Training			
Miscellaneous Supplies			
Startup/Testing			$10,000
Readiness Reviews/Management Assessment/Administrative Costs			
Other Capital Investment (explain)			
Subtotal: Installation Operating Expenses = (E)			$10,000
All company adders (G&A/PHMC Fee, MPR, GFS, Overhead, taxes, etc.)			
Total Project Funding Requirements = (C + E)			$140,000
Useful Project Life (L) (Years)=	10	Time To Implement (Months)=	6
Estimated Project Termination/Disassembly Cost (if applicable) (D) =			
RETURN ON INVESTMENT CALCULATION			
ROI = (B – A) – [(C + E + D)/L] x 100 =			48.56%

O&M Annual Recurring Costs		Project Funding Requirements	
Annual Costs, Before (B) =	$163,964	Capital Investment (C) =	$130,000
Annual Costs, After (A) =	$81,982	Installation Op Expenses (E) =	$10,000
Net Annual Savings (B – A) =	$81,982	Total Project Funds (C + E) =	$140,000

BEOL PROCESS CHANGE

Worksheet 3: Estimate Basis

ASSUMPTIONS FOR BEOL PROCESS CHANGE

The costing analysis uses the assumption that changes to the BEOL process will reduce PRS-1000 by 50%. It is also assumed that this process change will take 18 months to complete.

EXISTING TECHNOLOGY

PRS-1000 is being used in the BEOL before metal/oxide deposition and after CMP. A typical wafer processed in the BEOL will cycle through these processes 20 times before final produce is achieved. Therefore, a wafer typically goes through the PRS-1000 tool 20 times.

PROPOSED P2 TECHNOLOGY

PRS-1000 is used as a pre-metal/oxide deposition stripper. This is not needed since the wafer has already been cleaned through the process at the Asher. Also, using PRS-1000 after CMP is not needed. CMP, in itself, cleans the wafer off and removes any material that PRS-1000 would. Therefore, the proposed technology is to remove the PRS-1000 step prior to metal/oxide deposition and after CMP. This change will reduce the PRS-1000 use by at least 50%.

COST SAVINGS, COST AVOIDANCE, AND RISK REDUCTION

The cost savings and avoidance would be 50% off the purchase and disposal costs. This process change will require a qualification process which will cost in time and labor. $25K was assessed for Start-up and testing. $5K was assessed for planning and procedural development.

Worksheet 1: Operating and Maintenance Annual Recurring Costs

Expense Cost Items	Before (B) Annual Costs		After (A) Annual Costs
Equipment			
Purchased Raw Materials and Supplies			
Process Operation Costs:	$18,000		$9,000
Utility Costs			
Labor Costs			
Routine Maintenance Costs for Processes			
Process Costs			
Other			
Subtotal	$18,000		$9,000
PPE and Related Health/Safety/Supply Costs			
Waste Management Costs:	145964		72982
Waste Container costs			
Treatment/Storage/Disposal Costs			
Inspection/Compliance Costs			
Subtotal	$145,964		$72,982
Recycling – Material Collection/Separation/Preparation Costs:			
Material and Supply Costs			
Operations and Maintenance Labor Costs			
Vendor Costs for Recycling			
Subtotal	$0		$0
Administrative/Other Costs			
Total Annual Cost:	$163,964		$81,982

Worksheet 2: Itemized Project Funding Requirements (One-Time Implementation Costs)

Category			**Cost $**
INITIAL CAPITAL INVESTMENT			
Design			
Purchase			
Installation			
Other Capital Investment (explain)			
Subtotal: Capital Investment = (C)			$0
INSTALLATION OPERATING EXPENSES			
Planning/Procedure Development			$5,000
Training			
Miscellaneous Supplies			
Startup/Testing			$25,000
Readiness Reviews/Management Assessment/Administrative Costs			
Other Capital Investment (explain)			
Subtotal: Installation Operating Expenses = (E)			$30,000
All company adders (G&A/PHMC Fee, MPR, GFS, Overhead, taxes, etc.)			
Total Project Funding Requirements = (C + E)			$30,000
Useful Project Life (L) (Years)=	10	Time To Implement (Months)=	18
Estimated Project Termination/Disassembly Cost (if applicable) (D) =			
RETURN ON INVESTMENT CALCULATION			
ROI = (B – A) – [(C + E + D)/L] x 100 =			263.27%

O&M Annual Recurring Costs		Project Funding Requirements	
Annual Costs, Before (B) =	$163,964	Capital Investment (C) =	$0
Annual Costs, After (A) =	$81,982	Installation Op Expenses (E) =	$30,000
Net Annual Savings (B – A) =	$81,982	Total Project Funds (C + E) =	$30,000

FEOL PROCESS CHANGE

Worksheet 3: Estimate Basis

ASSUMPTIONS FOR FEOL PROCESS CHANGE

The costing analysis uses the assumption that changes to the FEOL process will reduce the amount of PRS-1000 required by 20%. Also, the purchase price will be reduced because Piranha costs 50% less than PRS-1000 at this time. It is also assumed that this process change will take 12 months to complete.

EXISTING TECHNOLOGY

PRS-1000 is being used to strip polymers after the Asher in the FEOL.

PROPOSED P2 TECHNOLOGY

Replace PRS-1000 with Piranha as the polymer strip. Piranha is a more effective and can be sent to the AWNS rather than disposed of as hazardous waste.

COST SAVINGS, COST AVOIDANCE, AND RISK REDUCTION

Costs incurred (time and labor) will be determined by the qualification requirements. It was assumed that $10K in start up and testing and $5K in planning/procedural development would be assessed. Disposal costs will be waived and the risk of yield loss will be reduced by the eliminated cross-contamination potential of high metals.

No capital investment is required.

The cost of Piranha is 50% less than PRS-1000 and may be less if bulk is purchased.

Worksheet 1: Operating and Maintenance Annual Recurring Costs

Expense Cost Items	**Before (B) Annual Costs**		**After (A) Annual Costs**
Equipment			
Purchased Raw Materials and Supplies			
Process Operation Costs:	$18,000		$7,200
Utility Costs			
Labor Costs			
Routine Maintenance Costs for Processes			
Process Costs			
Other			
Subtotal	$18,000		$7,200
PPE and Related Health/Safety/Supply Costs			
Waste Management Costs:	145964		116771.2
Waste Container costs			
Treatment/Storage/Disposal Costs			
Inspection/Compliance Costs			
Subtotal	$145,964		$116,771
Recycling – Material Collection/Separation/Preparation Costs:			
Material and Supply Costs			
Operations and Maintenance Labor Costs			
Vendor Costs for Recycling			
Subtotal	$0		$0
Administrative/Other Costs			
Total Annual Cost:	$163,964		$123,971

Worksheet 2: Itemized Project Funding Requirements (One-Time Implementation Costs)

Category			Cost $
INITIAL CAPITAL INVESTMENT			
Design			
Purchase			
Installation			
Other Capital Investment (explain)			
Subtotal: Capital Investment = (C)			$0
INSTALLATION OPERATING EXPENSES			
Planning/Procedure Development			$5,000
Training			
Miscellaneous Supplies			
Startup/Testing			$10,000
Readiness Reviews/Management Assessment/Administrative Costs			
Other Capital Investment (explain)			
Subtotal: Installation Operating Expenses = (E)			$15,000
All company adders (G&A/PHMC Fee, MPR, GFS, Overhead, taxes, etc.)			
Total Project Funding Requirements = (C + E)			$15,000
Useful Project Life (L) (Years)=	10	Time To Implement (Months)=	12
Estimated Project Termination/Disassembly Cost (if applicable) (D) =			
RETURN ON INVESTMENT CALCULATION			
ROI = (B – A) – [(C + E + D)/L] x 100 =			256.62%

O&M Annual Recurring Costs		Project Funding Requirements	
Annual Costs, Before (B) =	$163,964	Capital Investment (C) =	$0
Annual Costs, After (A) =	$123,971	Installation Op Expenses (E) =	$15,000
Net Annual Savings (B – A) =	$39,993	Total Project Funds (C + E) =	$15,000

100% Implementation Summary - Estimated

The current total costs for chemical purchases and hazardous waste disposal is $198,684. This is based on data received from July 2005 thru June 2006.

If all the options under Opportunity 1 were implemented the PRS-1000 Photoresist Stripper annual costs would be reduced from $163,964 to $32,793. This is a savings of over $131,000 per year. Purchase, installation, and start-up/testing of this system have an estimated cost of $185,000. The payback of these options will be a little over a year.

Opportunity 1:

PRS-1000 Current Annual Costs:	**$163,964**
Titration System Implementation (50% reduction):	$81,982
BEOL Process Change (50% reduction):	$40,991
FEOL Process Change (20% reduction):	$32,793
PRS-1000 New Annual Costs:	**$32,793**

If Opportunity 2 and 3 were implemented the HF Contaminated Materials would be reduced by 50% and the Acetone wipes would be reduced by 100%. Currently, Opportunity 2 costs $23, 520 per year in disposal costs. Opportunity 3 costs $11,200 in disposal costs.

Opportunity 2:

HF Contaminated Materials Annual Costs:	**$23,520**
Glove Rinse (50% reduction):	$11,760
HF Contaminated Materials New Costs:	**$11,760**

Opportunity 3:

Acetone Wipes Annual Costs:	**$11,200**
Use wipes until dry (100% reduction):	$0
Acetone Wipes New Annual Cost:	**$0**

Current Annual Costs:	$198,684
Reduction in Costs:	($154,131)
New Annual Costs:	**$44,553**

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