

DESIGN IMPACTS OF SEGREGATION AND CHARACTERIZATION OF RECLAIM WASTES

Thomas Gutowski/Industrial Design Corporation, Portland, Oregon
Ralph Williams/Industrial Design Corporation, Portland, Oregon

INTRODUCTION

This paper focuses on reclaim of process rinse waters for reuse in the ultrapure water system. The concept of deionized water reclamation is not a recent development within the semiconductor manufacturing industry. A reclaim system can be an asset to the owner and reap a multiple benefits. The reuse of UPW rinse waters from areas that are not susceptible to heavy loads of chemical contamination can benefit UPW system water quality, be cost effective, and conserve water resources. However, if safeguards are not introduced into the system, catastrophic consequences could occur to the reclaim system and even to the main UPW system. The reuse of high-quality water for different processes has been in existence for quite some time. One of the original reasons for reuse was the cost of producing deionized water. If the feed water quality to the front end of a water treatment system was increased by the dilution of high-quality reclaimed deionized water, it was reasoned that the production costs for UPW would decrease. However, in the earlier years of reclaim use, the water quality was not easily understood and the instrumentation used to determine water quality not very sophisticated. If the water quality was 5 megaohm-cm or better and the pH between 5 to 8, then it was thought that the water quality was sufficient for reclaim. Total organic/oxidizable carbon was not considered when reclaim systems were in the initial development stages. Instrumentation for accurate and rapid analysis of TOC was not available. Low-level concentrations of organic compounds used in the semiconductor manufacturing process were responsible for failures in system components in which the reclaim water was introduced. Photoresist and photoresist developers and strippers, organic solvents, and other semiconductor process chemicals can destroy the function of RO membranes or irreversible foul resin. Today there is a better understanding of the factors that need to be considered when reclaim systems are designed, built, monitored, and operated.

There are several steps one should take in the facilities design approach for a reclaim system. A project definition must be developed to identify the project objectives that are the conceptual background upon which the system is designed. Factors such as preliminary and final design, realization of project scope and construction, and startup and qualification are integral parts of the entire process. There are design/construction issues and milestones that govern the acceptance and feasibility of the reclaim system. These factors are site/plant configuration, cost estimating, coordination, and system qualification.

PROJECT DEFINITION

There are many reasons for the justification of a reclaim system on a new facility project. A single reason may be the driving factor, or there may be a combination of factors. The reduction of water consumption may be a goal. This may be driven by water supply to the manufacturing site, whether it be a municipal source or by water obtained on site. A

municipal water source could impose water-use restrictions because their water supply is limited due to source limitations. Water quality from a municipal treatment facility can vary significantly on a seasonal and source basis, and the UPW treatment facility may want to dampen the variability by the introduction of the reclaim system.

Another factor may be the desire to reduce the wastewater discharged from the manufacturing facility. Again, there may be discharge limitations placed upon the manufacturing facility by the municipality within which the facility discharges its wastewater.

Along with onsite treatment, the discharge into a receiving water body is usually such that discharge quantity and quality may be limited by the discharge permitting agency. The concept of "near zero discharge" from manufacturing facilities; has been in the forefront of state legislative policy and industry may be forced to abide by this policy. It is significant to consider that wastewater from a facility with DI reclaim is likely to be more concentrated than from one without a reclaim system.

If the reason for a reclaim system is a reduction in the cost of UPW produced, then a cost/benefit analysis must be considered. This analysis needs to take into account the cost of the base UPW production, equipment costs associated with the reclaim system-4 and the cost of operation and maintenance. The risk factor of reclaim must be considered but is difficult to quantify. The production of UPW with a significant portion of the feed water as high quality reclaim water may improve the overall quality of the UPW delivered to the manufacturing fab. Reduction of TOC, silica, and other contaminants could be a benefit. In order to achieve the optimum design, the specific goals and criteria for reclaim must be established early in the project.

Reclaim Use. Utilization of reclaim water is varied and can potentially be used for any application where normal feed facilities water is used. This includes the obvious application as makeup to the UPW system or site industrial process waters, such as cooling and heating, humidification, and others. The segregation of different qualities of reclaim water can be achieved and these used for different processes. Preliminary evaluation of water and re-use points are identified in a site water balance schematic. This schematic becomes the basis for subsystems design and interrelationship.

Reclaim Sources. The obvious sources for reclaim waters are the points of UPW use. These include wet stations, support areas, such as mask production facilities and assembly and cleaning processes, that support wafer processing. The reclaim of waters from wet stations, which represents the largest volume, needs further consideration as to the type of process associated with the wet station and the portion of the wet station from which the rinse water is reclaimed. Assuming most wet stations incorporate a multi-step rinse cycle following a chemical bath, a method of segregating the rinse water by time or cycle should be considered. Concentrations of contaminants in these tanks are at the highest levels, and their potential for contamination of the process reclaim stream is high.

Process tools and wet station tanks that should be avoided are ones that contain organics, such as tetramethyl ammonium hydroxide (TMAH), hexamethyl disilazane (HMDS), ethyl lactate, n-methyl pyrrolidone (nNP), isopropyl alcohol (IPA), glycerine/BF, surfactants, and

other organic compounds that can cause problems within the reclaim stream and the subsequent production of UPW. Some of these chemicals are hard to detect in the reclaim waste stream using conventional analytical instrumentation, and their introduction into the reclaim system should be avoided. However, it should not be assumed that these chemicals will not enter the reclaim stream, and analytical testing for these contaminants should be part of the reclaim quality testing.

Reclaimed Water Quality and Volume

Crucial to the initial design process and an important aspect of the design and cost/benefit analysis are the consideration of the volume and quality of the UPW that can be reclaimed. This prediction would come from a survey of the process flow and consumption of the manufacturing area. A sufficient volume of reclaim water is needed to make economical the addition of capital equipment and piping needed for the treatment of the reclaim water. Also needed is tool data as to process times, high-low flow duration, and tool utilization. Again, consideration needs to be given to the process chemistry and exclusions based upon the ability to detect contaminants, the nontreatability of the contaminant, or the detrimental effect upon the reclaim treatment equipment. Although detailed tool information is not generally available early in the project, assumptions must be made to establish project design criteria.

For purpose of discussion, a generic 0.8-micron DRAM manufacturing facility of 60,000 square feet (gross cleanroom area) is considered. Based on industrial engineering analysis, this fab would consume an average of 540 gpm of ultrapure water distributed to the following general process types:

BF only processes	24 percent	130 gpm
SC-1 processes	26 percent	140 gpm
SC-2 processes	26 percent	140 gpm.
BOE processes	4 percent	22 gpm
Sulfuric/regist strip processes	18 percent	98 gpm
Silicon etch (BF/nitric) processes	1 percent	5 gpm

Photolithograph processes

1 percent

5 gpm

This breakdown will be substantially different for other product types and recipes, incorporating CMP, plating, and other complicated chemistries. Analysis of these streams for re-use will be driven by the previously established criteria, cost, final wastewater constraints, risk, etc. This could result in various segregation concepts.

One scenario would be to collect a reasonable volume of very high-quality water. If the first rinse of each process is discarded (one-fifth of total UPW use), and photoprocess are eliminated, 428 gpm of reclaim with low levels of inorganic contaminants could be collected (79 percent reclaim). This appears aggressive but, for the assumed process mix, is not unreasonable. The first rinses, minus photolithography would produce 107 gpm of very low quality reclaim which could be retreated or discharged to waste.

The net effect of this type of analysis is to establish the number, sizes, and quality of each collection/treatment system required.

PRELIMINARY DESIGN

Foremost in the design process is the consideration of stream segregation in the design and construction of the collection system. Elimination of undesirable components in the reclaim stream such as chemical content and concentration, organic chemical components, and fluoride content need to be considered in the design of the collection system. This information would be gathered in the initial survey of tool use. The number and type of drains need be determined from the above information. The distribution of the wet stations and sources of reclaim waters from support areas should be considered in their ability to be serviced by a collection system and the volume contribution to the reclaim stream. Sufficient volume from a wet station is required to justify the cost of the design, construction, and maintenance of the piping system serving that tool or process area.

Data from the tool sources must include peak and average flows and chemical content, such as whether the chemical compound is an acid, base, or organic. The peak and average chemical contents of the potential waste reclaim streams must be understood before implementation of a recovery program. Testing of the waste stream from the tools for chemical content needs to occur in order to obtain the necessary information as to whether the waste stream from that tool will be acceptable for reclaim treatment.

The various collection methods need to be evaluated and the most cost-effective solution adopted. Gravity drains to lift stations and then feed to a qualification tank would be the simplest method of collection. The number and location of these lift stations and the piping to the main treatment area need to be incorporated in the design. However, very small quantities of undesirable components of the waste stream could potentially contaminate the entire contents of the collection tank necessitating the dumping of the tank. Methods of detection of undesirable components within the reclaim stream need to be employed, and the undesirable materials should be diverted prior to the collection tank. This water quality detection is key to

a successful reclaim program. Detection of undesirable or untreatable waste components and the diversion of this waste protects the reclaim system from upsets and possible failure of components of the reclaim treatment system. The location of the analytical components- must ensure that the quality of the reclaim stream remains within the set specifications. These specifications should include such parameters as TOC, resistivity, pI-L o3ddation/reduction potential, GC analysis for organics, ion-selective instruments, and other parameters that are of concern relative to the treatment process. New method of rapid on-line detection may need to be developed in order to eliminate undesirable components within the reclaim stream. The levels of contaminants need to be established with regards to the treatment capabilities of the reclaim process equipment. This instrumentation must be on-line and real-time analysis. Diversion of the waste strewn must be controlled by this instrumentation, and diversion needs to be rapid so that the reclaim equipment is protected and the quality of the water from the treatment process remains relatively constant.

When the nature of the reclaim stream is understood, a treatment strategy is drawn up with regards to the treatment process. An integral part of the preliminary design is an understanding of the process flow and the generation of process flow diagrams for the re-treatment process. These documents contain the components of the treatment system, along with the unit operations, component sizes, and points of reuse. To understand the goals of the reclaim system, a preliminary conceptual design with respect to treatment and operations is necessary. The primary control philosophy is contained in these documents. Treatment scenarios can be discussed concerning the specific reuse of the reclaim waters. The treatment of the reclaim water may be accomplished by a stand-alone system that is dedicated to reclaim waters only, or the reintroduction may be back to the primary UPW makeup system. Wherever the reintroduction takes place, a thorough understanding of the chemistry of the reclaim waters is essential in effective treatment and the protection of the components that are part of the treatment process. Diversion of reclaim waters that are outside the set specifications is essential to maintain the integrity of the system and the water quality of the final product. This can be accomplished at many alternate locations within the reclaim system. Diversion can occur at the tool, at primary collection points, or the feed to the final collection/equalization pretreatment system. Diversion could also occur at multiple points within the system in order to have redundant checks for protection of the system.

The final stage of the preliminary design phase is to obtain a cost estimate for the system. From this information a cost/benefit analysis can be made, and a decision made whether or not to proceed with the final design. If the decision is to proceed to the final design stage, the conceptual or preliminary design becomes the basis for subsequent activities.

FINAL DESIGN

The final design phase incorporates the preparation of engineering drawings that designate the specifics for the construction of the reclaim system. Piping system details specify the types of materials, routing of piping, placement of other system components, slopes of piping, detailed sizing, and all other installation details for the reclaim system. Details for the equipment and operation of the system, both analytical and treatment, are chosen at this point in the pre-construction phase. Instrument selection is finalized, along with the control details and set points that the system will operate under. Equipment details include the specifications

needed for treatment components, such as tanks, pump sizing, and materials of construction. The materials selected need to be compatible with the type of reclaim water encountered and also compatible with a high-purity water system. Installation details specify procedures for piping fabrication, equipment, and piping component layout, and other aspects of system design which are not part of MID drawings.

Another approach to be considered in the final design phase are the details associated with the diversion and qualification of the reclaim water. In conjunction with the above is the collection and transfer of quality reclaim water to the treatment system. Instrumentation selection and location is critical to the treatment process. The instruments need to have the capability of real-time analysis and the capacity for data transfer to a control system which in turn controls diversion of reclaim water outside the specification limits. Placement of the analytical instruments for the determination of acceptable water can occur at several points within the collection and treatment system. Screening instruments can be placed at the outlet of the tool so that diversion occurs at the source. Redundant instrumentation can be placed at primary collection points, such as transfer pumps. The types of screening instruments should be kept simple for this preliminary diversion, such as pH and conductivity. Instruments such as pH, redox, conductivity, and ion-selective electrodes have the ability for rapid analysis and real-time data transfer. However, instruments such as a TOC analyzer and instruments for the determination of problematic organic compounds have analysis times that could cause bypass of reclaim water that is outside the specification set points. These instruments may be best located at the final collection/equalization tank prior to re-treatment. At this point in the pretreatment process, the final decision is made as to the acceptability of the reclaim water for further treatment. However, the quantity of reclaim water that could potentially be rejected is high. What is needed is real-time instrumentation that can eliminate potential organic contaminants at the source.

Instrument control details and set points for acceptance of the reclaim water for reuse are based on the treatability of the water by the process equipment. Again, cost benefit analysis is necessary in the final design of the system. Most semiconductor rinse waters and other UPW process waters can be treated; however, the equipment and associated costs with treatment need to be evaluated. Capital equipment and operation/maintenance costs must be identified to determine if the costs associated with treatment are less than the costs associated with disposal to a waste stream.

CONSTRUCTION

The emphasis for this stage of the process is to monitor the conformance of the actual physical installation with the engineered design. Design changes will be made during this phase, but the basic treatment philosophy and design should not be significantly changed.

STARTUP AND QUALIFICATION

The startup of the process equipment should be carried out in the normal sequential manner according to system design and process flow. This startup should be under a "no load" condition from manufacturing. Source water can be UPW if sufficient quantity can be provided or the use of municipal or UPW makeup water would be adequate. Piping from the

reclaim sources should be checked for leaks, lift stations should be checked for level control and proper operation,- and the individual components of the treatment system tested to ensure that proper operation and component performance is acceptable before the reclaim water reaches the reclaim treatment system. A ramp up or slow introduction of the reclaim water should take place. Certain tool sets or process tanks that are known to contain components that can be easily treated should be brought on line first; such as final rinse tanks or rinse tanks prior to the final rinse tank. The introduction of reclaim water sources should proceed from the cleanest sources to what is considered the most contaminated. This information would have been gathered during the initial design phase. Validation of the design flow and quality of the effluent should occur during this initial operation of the system. The validation of the treatment system is based on the expected versus the actual reclaim water quality. If the expectation and actual operation and quality specifications are met or exceeded, then the system theory and design were on target. However, if the actual reclaim water quality is not as expected, then a thorough evaluation of the system is necessary to pinpoint and correct the deficiency.

One precautionary addendum needs to be addressed when operating a reclaim system. There are no guarantees that the quality of the reclaim stream will stay constant from a particular tool or process sector. Changes in tool process chemistry are constantly changing and can significantly change the reclaim water quality from a particular wet station. A dialog needs to be established between the manufacturing sector and the facilities department that oversees the operation of the reclaim system. Process changes need to be evaluated for treatability by the reclaim system prior to their introduction into the reclaim treatment stream. This emphasizes the need for the initial diversion of undesirable water quality to be at the tool where the reclaim water originates.

ALTERNATIVE APPROACH

An alternative approach is to plan for a reclaim system in the initial design/construction of a new manufacturing facility. The system would be completed through the preliminary design stage. Preservation of space and future budget planning for treatment equipment and operations would be a forward-looking approach. The complete detailed design and collection of analytical information can put one well ahead when the reclaim system becomes more than a concept. Validation of the system design and the expected water quality of the final reclaim process using a pilot plant concept could save valuable time and expense when instituted prior to the design and construction of a full-scale process system. From the information gained in the operation of a pilot reclaim system, process adjustments can be made in the final design so that the optimum cost/benefit ratio can be achieved, along with the highest water quality.