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Achieving Process Utility Conservation and Cost Reductions in a 200-mm Fab Environment

Wayne Curcie, Kenneth Hill, Billy Jones, Leo Meire, and Tom Stagg, Qimonda (formerly Infineon Technologies)

Volatile market pressures, global competition, and increasingly complex technology continue to challenge the microelectronics industry. While the drive to increase performance and decrease costs is not new to the semiconductor industry, the weak market and price erosion in the DRAM sector create special cost pressures that require a concerted response.

This article addresses process utility conservation efforts and cost reductions at Qimonda's DRAM manufacturing facility in Richmond, VA (formerly Infineon Technologies). The fab's efforts have focused on five main areas: clean dry air (CDA), water, exhaust, cleanroom air, and process cooling water. Implemented over a nearly two-year period, The measures undertaken at Qimonda have reduced site operating expenses by more than $1 million a year. Utility cost savings, in turn, have helped to reduce production costs. Conservation efforts have also led to increased reliability while decreasing the capital expenditures required to support production changes.

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Phone 925-399-6246
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Taipei, Taiwan

October 2006

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Hilton Austin Airport, Austin, TX

10 WWK Paper "CMP Productivity Improvement Using Pad Surface Management" @ ISMI Symposium
4:05pm, Bergstrom Ballroom AD
Hilton Austin Airport, Austin, TX

10-11 Industry Strategy and Technology Forum
Yokohama, Japan

November 2006

5-8 International Trade Partners
Kohala Coast, Hawaii

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3-6 Winter Simulation Conference
Monterey Conference Center
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Makuhari Messe
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6-8 SEMICON Japan
Makuhari Messe
Chiba, Japan

Undertaking Utility Conservation

The optimization of process utilities has many benefits, including conservation of resources, reduced operating and production costs, and investment cost savings. In most cases, implementing effective conservation efforts requires a significant amount of planning. In many cases, the improvements can be difficult to measure directly.

Utility conservation efforts lower manufacturing costs in two important ways. First, the cost per bit decreases as operating costs decrease. Second, in situations where utility systems are operating near capacity, conservation allows fabs to add production equipment without costly investments in system upgrades, thus diluting fixed costs and decreasing incremental variable costs. In limited instances, fab utility conservation has also improved equipment performance and system reliability.

As Figure 1 indicates, electricity and water costs decreased since conservation efforts were initiated, while factory output (manufactured layers per week) increased steadily. The figure demonstrates the difficulty of determining the impact of conservation as other factors change. For example, wafer output per week, device complexity, and even weather conditions have a significant effect on electrical consumption.

In implementing conservation measures, the most immediate and daunting challenge can be determining where and how to begin. A relatively simple and useful approach is to determine the cost per year and cost per unit (e.g., dollars per gallon per minute or standard cubic foot per minute) for each process utility.[1] That information is also necessary to make cost-benefit assessments of potential conservation efforts.

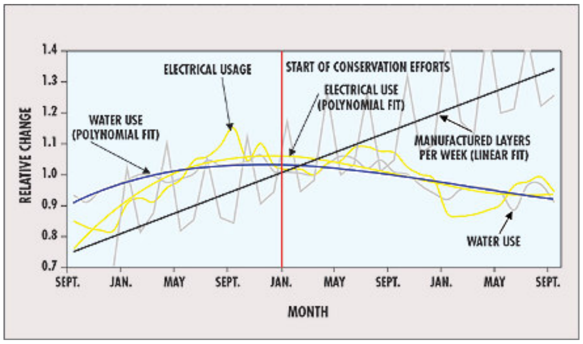

Figure 1: Relative change in the electricity and water costs over a three-year period. (The x-axis has been normalized to indicate the relative change in cost and output from an arbitrary baseline just before the start of conservation efforts.)

Although it can be difficult to determine, knowing the percent contribution of various processes and materials to the overall cost per manufactured layer can be beneficial. For example, Figure 2 indicates the relative contribution of three cost categories: tool maintenance (including parts and consumables), utilities (electricity, water, and natural gas), and process materials (chemicals, gases, test wafers, and targets). Figure 3 shows the relative impact of basic utilities and process materials (e.g., bulk and process gases) on product cost.

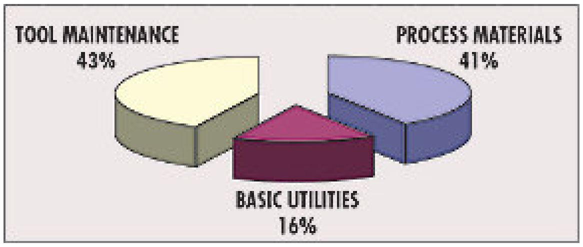

Figure 2: Contribution of three fab expense categories to facilities costs.

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[1] International Sematech, "Fab Utility Cost Values for Cost of Ownership (COO) Calculations," Technology Transfer No. 02034260A-TR (Austin, TX: Sematech, 2002 [cited 30 March 2006]); available from Internet: www.sematech.org/docubase/document/4260atr.pdf

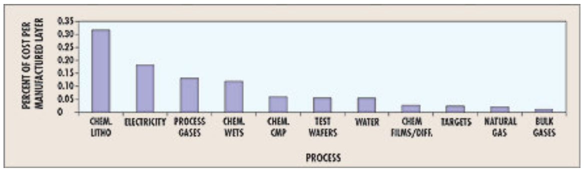

Figure 3: Relative impact of basic utilities and materials (e.g., chemicals, electricity, wafers, water, and process and bulk gases) on product cost.

Based on 2003 data, Figure 4 provides the contribution of three basic utilities—electricity, water, and natural gas—to product costs. Not surprisingly, electricity is the largest component. Figure 5 presents the amount of electricity used per fab area, which includes administration (office lighting, heating, and air conditioning); the gas pad (production equipment for CDA, nitrogen, oxygen, and cryogenic gases such as argon, hydrogen, and helium); the central utility building (hot water, chilled water, PCW, and UPW); and the fab (process tools and cleanroom exhaust). As shown in the figure, production equipment is the greatest contributor to electrical costs. The next-largest contributors are the central utility building and the gas pad.

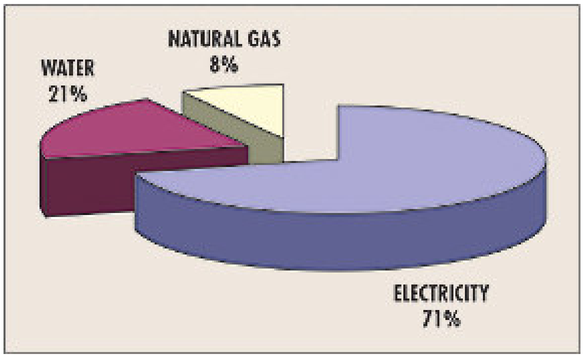

Figure 4: Contribution of three basic utilities—electricity, water, and natural gas—to product cost.

In some cases, where and how to initiate utility conservation measures may be driven by capacity limitations, which lead to optimizations and conservation, or to capital investment and system additions.

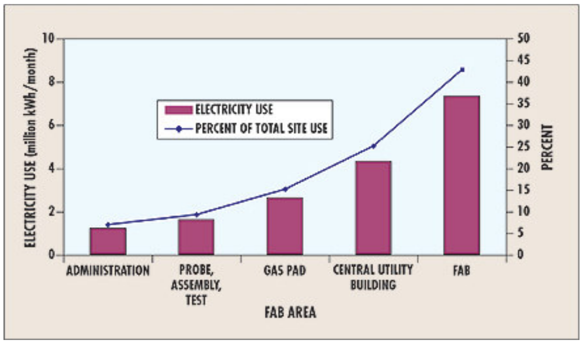

Figure 5: Electricity use breakdown per fab area.

The following sections describe the efforts that were undertaken at Qimonda to reduce utility consumption. Many of the measures that were implemented can be used in any semiconductor manufacturing facility. Whatever approach a fab takes, success requires a sustained commitment and attention to detail.

CDA Conservation

CDA is used throughout the factory and support areas, including in pneumatic controls and tools, air cylinders for machine actuation, and air-driven pumps. In addition, it is used for purging, product cleaning, and blow-off. CDA systems in the fab are normally designed to provide –60° to –100°F dew point air with 0.01- to 0.003-µm filtration. Delivered pressure to the point of use is generally 100 to 120 psig.

Design data from numerous fabs indicate that CDA consumption can vary significantly from 25 to 50 std cu ft/min per 1000 sq ft of production cleanroom area. Its use in newer fabs seems to be closer to a nominal 40 std cu ft/min per 1000 sq ft. Typically, more than 80% of CDA consumption supports manufacturing equipment, while remaining 20% is used for instrument air and utility applications. At

Qimonda, the largest manufacturing consumers of CDA are the wet and photolithography process areas, as highlighted in Figure 6. Each area uses approximately15% of the fab's CDA.

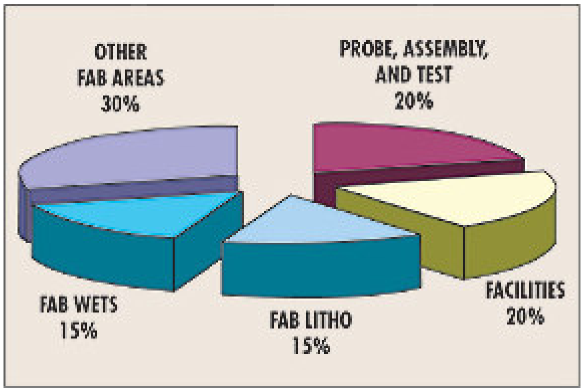

Figure 6: Site CDA use per fab area.

CDA systems typically consist of multiple compressors, dryers, and filters that are located in a central utility building. Presumably to focus capital and personnel resources on IC manufacturing, fabs have contracted gas vendors to supply CDA systems in recent years. CDA is widely distributed throughout the site and the factory. CDA piping distribution systems in the probe, assembly, and test (PAT) building each serve several hundred users.

A good deal of information is available to help fabs initiate CDA conservation efforts[3]. Qimonda engineers first used this information, along with site usage data, to improve the areas with the highest CDA consumption. For each area, they met with representatives to review the project objectives, tool lists, and specific compressed-air applications. Then they performed a field review of tools and other air users, comparing setpoints on similar toolsets and refining conservation opportunities.

During the CDA survey, the engineers found that performing mechanical or process-related work with compressed air energy can be 7 to 10 times more expensive than doing the same work with electrical energy [2]. Hence, the most promising opportunities involved improving the use of compressed air. The literature emphasized that equipment maintenance reviews can result in other conservation steps, including using mechanical mixing instead of sparging or agitation, fixing leaks, standardizing flow and pressure setpoints on similar equipment, implementing process vacuum or independent vacuum pumps in place of venturi vacuum generation, using blowers or air-conditioning units instead of CDA in such applications as equipment cooling or combustion air, and avoiding the use of continuous air in intermittent applications.[3]

While some fab areas must use pneumatic drives for safety reasons and some equipment cannot use process vacuum systems because of the presence of liquids, more-efficient use of these systems is possible. At Qimonda, for example, alternative solutions were implemented where feasible, as shown in Table I. Several of these modifications warrant explanation.

- In the facilities area, the original agitators on the fluoride waste-treatment tanks had been unable to mix the liquid in the lower portion of the tank thoroughly. Therefore, air spargers had been added to the tanks to assist with mixing. As a result of the CDA conservation effort, the air spargers were replaced with new

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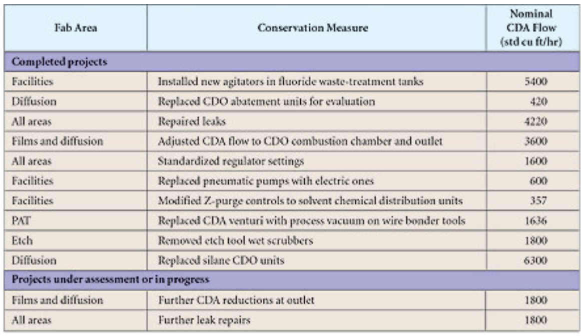
[2] F Moskowitz, "Compressed Air Systems Are Key to Productivity," Plant Services (January 2003): 51–55.

[3] Compressed Air Challenge, "Inappropriate Uses of Compressed Air," Fact Sheet No. 2 & No. 3 [online] [cited 30 March 2006]; available from Internet: www.compressedairchallenge.org

agitators, resulting in significant cost savings.

- In all fab areas, leaks were detected and repaired. Although such leaks were found at compression fittings or valve positioners and were generally of a minor character, checks of regulators and leaks have become part of regular preventive maintenance (PM).



Fab Area	Conservation Measure	Nominal CDA Flow (std cu ft/hr)
Completed projects		
Facilities	Installed new agitators in fluoride waste-treatment tanks	5400
Diffusion	Replaced CDO abatement units for evaluation	420
All areas	Repaired leaks	4220
Films and diffusion	Adjusted CDA flow to CDO combustion chamber and outlet	3600
All areas	Standardized regulator settings	1600
Facilities	Replaced pneumatic pumps with electric ones	600
Facilities	Modified Z-purge controls to solvent chemical distribution units	357
PAT	Replaced CDA venturi with process vacuum on wire bonder tools	1636
Etch	Removed etch tool wet scrubbers	1800
Diffusion	Replaced silane CDO units	6300
Projects under assessment or in progress		
Films and diffusion	Further CDA reductions at outlet	1800
All areas	Further leak repairs	1800

Table I: CDA conservation activities by fab area. Total CDA consumption has been reduced by 25,933 std cu ft/hr, or 11%. Potential reductions amount to another 3600 std cu ft/hr.

- Field reviews performed throughout the factory included checks of regulator outlet pressure setpoints. Some regulators deviated from those on similar tools. Area representatives reviewed those tools and standardized the regulators. Since then, setpoint verification has become part of PM activities.
- During a review of the fab's controlled decomposition oxidation (CDO) abatement units, inconsistencies were observed in the units' pressure setpoints and airflow rates. In response, airflow and pressure were reset to the manufacturer's recommendations. At the same time, it was determined that the units' CDA use was inefficient and that they required a significant amount of maintenance. Hence, after undergoing a separate evaluation, alternate abatement units with a lower cost of ownership were purchased to perform silane abatement. A benefit of the new units is that they do not require CDA, nitrogen, or water.
- In one case, the vacuum requirement for a group of tools was converted from CDA (vacuum venturi) to process vacuum. That modification not only reduced CDA consumption, but also improved tool reliability, throughput, and uptime because seals in the venturi wore out over time and decreased vacuum performance. The use of process vacuum is more reliable than vacuum venturi and has a lower operating cost.

Although the initial portion of the CDA survey has been completed, several conservation avenues are still being pursued. For example, further investigation and testing are necessary to determine if the air used at the CDO outlet can be reduced further. Efforts to find and repair minor leaks continue during PM activities. As time permits, specific areas (typically those with many compression fittings) are surveyed for leaks using an ultrasound detector.

As illustrated in Figure 7, the greatest successes in CDA conservation have been achieved by eliminating or optimizing inefficient compressed-air applications. Areas that use large amounts of air for agitation, combustion, and purging have experienced greater air reductions than areas with much higher overall consumption. In some cases, desired tool retrofits have not been carried out because of the amount of downtime required, the cost of the retrofit, and the sensitivity of the process. Hence, it is important to give early consideration to conservation goals when devising tool specifications and to work with toolmakers to optimize utility use.

CDA conservation efforts at Qimonda are ongoing, and demand is periodically assessed and forecast based on production plans. To date, CDA consumption has been reduced by more than 25,000 std cu ft/hr, or 11%. The conservation measures have saved $100,000 by eliminating the need to increase CDA system capacity incrementally and potentially have saved $1 million by eliminating the need for a major upgrade. Depending on the site conditions (the cost of electricity, system configuration, etc.), CDA conservation can also result in energy savings.

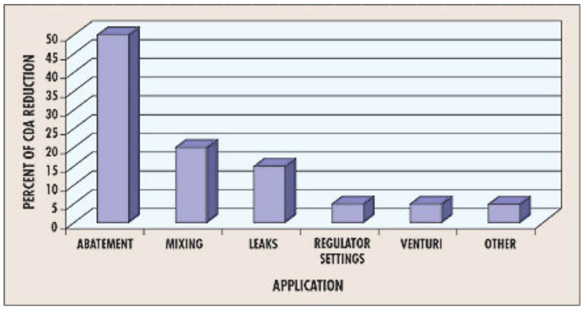


Figure 7: Percent of CDA reduction resulting from various improvements.

Water Conservation

The UPW plant uses more water than any other fab area, as illustrated in Figure 8. Consequently, it made sense to begin water conservation efforts there. In the typical UPW plant, the reverse-osmosis (RO) units send more wastewater down the drain than any other equipment. A water purification technique, RO separates feedwater into clean product water and relatively concentrated reject water.

First-Pass RO Reject Recycle

In a UPW plant, two reverse-osmosis passes are employed in series, with the product of the first pass becoming the feed for the second. Commonly, the reject from the second pass is recycled into the feedwater for the first pass. However, concentrated first-pass reject water is sent down the drain. The design of an RO plant usually considers a worst-case feedwater scenario to ensure that the plant is able to process incoming water adequately. In actuality, feedwater quality is much better than design conditions, directly affecting the concentration of the first-pass reject stream, which is less concentrated than when the plant is operating on design-basis feedwater. Often incoming feedwater quality varies seasonally.

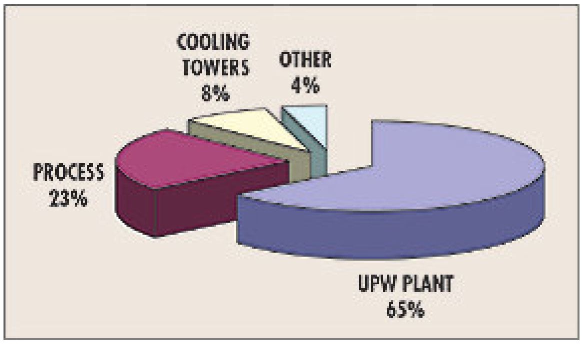


Figure 8: Site water use across the fab.

The UPW plant installed a system that recycles a portion of the otherwise-wasted first-pass reject water back into the incoming feedwater by directing it to the suction side of the pumps that supply the RO units—plant conditions and incoming feedwater quality permitting. If water quality or plant conditions change, the system can be stopped at once by closing a single valve, preventing water quality excursions from upsetting the process.

In 10 months of operation, the plant saved 6.5 million gallons of water, representing water and sewer cost savings of more than $20,000. The new system has not adversely affected either the functioning or water quality of the RO units.

RO Unit Cycling

Normal practice with RO units is to have more installed capacity than nominal plant output and to rotate units in and out of service to maintain storage-tank levels and ensure that none of the units are idle long enough for the water to become stagnant. When the product-water tank reaches a high level, the RO product is diverted back to raw-water storage at the front end of the plant. To prevent large amounts of reject water from going to the drain unnecessarily, RO unit rotations can be planned to minimize the amount of time that the product water is directed to the raw-water tanks. When it is time to shut down an RO bank, delaying the start of the next unit in the rotation until the product water tanks reach a low, but safe, level results in significant water savings at no cost. Operating the RO banks in this manner over a one-year period saved Qimonda more than 8 million gallons of water, or $25,000.

Reclaim Water from UPW Plant Operations

The reuse of water from instrument drains, RO pump vents, and vacuum-pump seals presents a significant opportunity for savings. While a single tool uses only a small amount of water, the collective flow rate in the fab is more than 10 gallons per minute. Additionally, the liquid-ring vacuum pumps that are typically used for degasification towers can consume seal water at a rate of about 20 gallons per minute in once-through mode. This water is of high enough quality that it can be used as feedwater for the cooling towers, replacing a substantial amount of city water without affecting tower-water chemistry. In the three years since this water began to be used, annual savings averaging more than 16 million gallons, or $50,000, have been achieved.

Exhaust Optimization

The original objectives of optimizing the exhaust system were to reduce the use of several highly utilized systems, lower operating costs, and enable the addition of new production tools with minimal exhaust-system upgrades. Early successes led Qimonda engineers to expand this effort into a continuous improvement project that encompassed all the exhaust systems in the fab.

Exhaust systems vary somewhat depending on the facility design. The Qimonda fab has four types of systems: process exhaust scrubbed (PES) for acids, process exhaust ammonia (PEA), process exhaust volatile organics (PEV), and process exhaust heat (PEH). The acid- and ammonia-abatement systems are induced-draft vertical counter-current-flow packed-tower scrubbers with redundant variable-speed fans. Located along the perimeter of the facility on a rooftop at the cleanroom level, the scrubbers treat chemical-laden exhausts from several fab areas. They vary in size and material based on the area served and exhaust type. Generally, the collection systems consist of one or more main headers with several laterals and serve up to several hundred points of use.

The exhaust optimization project started by determining exhaust costs and reviewing system performance and loading. The cost of exhausted air was determined to be approximately $5 per std cu ft/min per year.1 This figure included not only the energy cost required to run the exhaust fans (approximately 15%), but also the cost of conditioned cleanroom makeup air. System performance data (fan speeds, motor currents, static pressures, flows, etc.) were used to identify the most highly utilized systems. An arbitrary goal of reducing the fan speed to 85%, as shown in Figure 9, was established as a reasonable target to create available capacity and enable system maintenance without affecting production or the environment. With this and other information such as production plans, work on the various exhaust systems was prioritized.

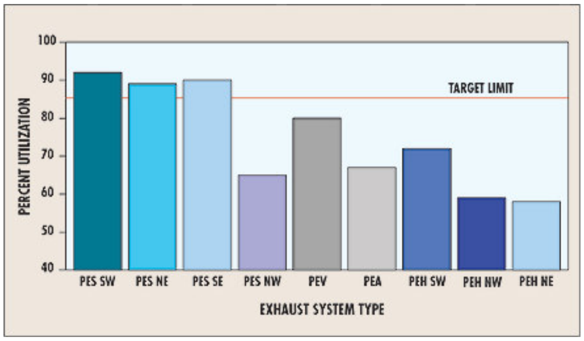


Figure 9: Utilization rates for different exhaust systems throughout the fab.

Through visual inspections, interviews with operations and production personnel, measurement of flow and static throughout the exhaust-collection system, and identification of large numbers of like equipment, the systems were examined to identify potential conservation opportunities. Modifications were made based on their value and feasibility. For example, support equipment and room-exhaust modifications were pursued before production tool exhaust reductions. Steps to reduce exhaust flow and static pressure included:

- Closing unused open blast gates from earlier renovations, idled equipment, or area exhaust systems that were installed during initial fab start-up.
- Measuring support-room exhaust flow and adjusting it to meet code requirements.
- Redirecting equipment heat exhaust to return air.
- Rebalancing support equipment (gas cabinets and chemical distribution units) based on SEMI S2-200 recommendations versus vendor flow and static pressure specs.[4]
- Adjusting exhaust flow and static pressure from process equipment gas boxes and enclosures according to SEMI S2-200 recommendations.
- Rebalancing lab hoods according to American Conference of Governmental Industrial Hygienists (ACGIH) recommendations.

The relative contributions of these activities are illustrated in Figure 10.

While savings efforts to date have not concentrated on tool-exhaust reductions, such reductions have been achieved by reducing film and etch gas-box exhausts and static pressure, per SEMI recommendations, pointing toward potentially significant opportunities in the future. Similar opportunities appear to exist in other areas as well—for example, diffusion, CMP, and implant. Work in these areas is being pursued when tools undergo downtime during PM activities. Further work in the etch area is also planned.

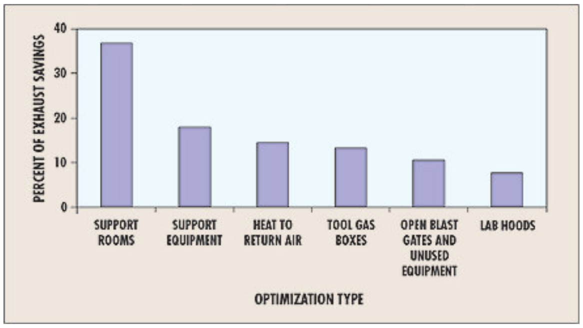


Figure 10: Percent of exhaust savings for various fab areas and equipment.

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[4] SEMI, "Design Principles and Test Methods for Evaluating Equipment Exhaust Ventilation," SEMI Standard S2-200 (San Jose: SEMI, 2001).

The first year of exhaust optimization efforts, highlighted in Figure 11, saved the fab $250,000. Moreover, exhaust reductions have freed up system capacity to support the installation of additional tools and technology changes. On several highly utilized systems, the engineers have increased reliability (in the event of fan failure) and eliminated the need to bypass the scrubber during fan maintenance. With the support of operations, manufacturing, and environmental safety and industrial hygiene, these reductions have been transparent to production and personnel. The fab plans to continue these efforts with a focus on production tools and the remaining exhaust systems.

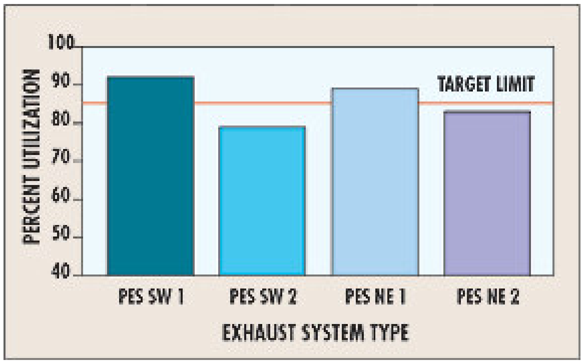

Figure 11: Exhaust utilization after initial exhaust system optimization.

Cleanroom Air Systems

Along with work in the exhaust area, several initiatives were undertaken to optimize the cleanroom air systems, which saved the fab more than $500,000 a year. The work consisted of several activities:

- Adjusting support-area temperatures and humidity.
- Reducing airflow and pressure in contiguous spaces (e.g., probe, assembly, and test).
- Reducing airflow and pressure in support areas immediately adjacent to the fab cleanroom.
- Decreasing fab cleanroom pressure and airflow.

The ultimate objective was to optimize cleanroom pressure and airflow without affecting production or lowering particle, temperature, and humidity performance. Hence, communication, as well as the sequencing and execution of the optimizations, was critical. First, airflow and pressure in the spaces adjacent to the cleanroom (e.g., the probe, test, gowning, and fab support areas) were examined and optimized. Once these areas had been stabilized, cleanroom pressure and then airflow were reduced.[5] Pressure inside the cleanroom was maintained at a higher level than outside or in adjacent spaces. In parallel with these efforts, temperature and humidity in nonadjacent support areas (e.g., the central utility building and electrical rooms) were evaluated and adjusted. These activities were coordinated with the exhaust reduction efforts, especially in spaces without pressure control. All in all, this work involved roughly 300,000 sq ft of manufacturing and support space and took nearly two years to complete.

Of all the fab's conservation efforts, optimizing the cleanroom air systems has been the most difficult to quantify. However, it is evident that the impact has been significant. First, the work enabled the fab to place major equipment into offline, standby mode, including one of three 50,000–std cu ft/min make-up air-handling units serving the probe, assembly, and test building; one of ten 50,000–std cu ft/min make-up air-handling units serving the fab; and a 50-ton chiller that supplies cooling water to the make-up air handlers. Second, the work reduced the fan run rates of the make-up air

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[5] R Cohen, "Energy Efficiency for Semiconductor Manufacturing Facilities," ASHRAE Journal 45, no. 8 (2003): 28–34.

handlers and 28 fan tower units serving the fab.

Process Cooling Water Conservation

PCW is used in all production areas to provide cooling for tool subcomponents such as vacuum pumps, cryogenic compressors, temperature control units (chillers and heat exchangers), and radio-frequency generators. The etch and film manufacturing areas together account for more than half of the facility's total PCW consumption, as illustrated in Figure 12. The next largest consumer is the lithography area, with 20% of the total flow.

The site's closed-loop PCW system consists of a nitrogen-blanketed collection tank and several centrifugal pumps that operate in parallel. Another pump remains in standby mode. The water recirculated by these pumps is cooled by the site's chilled water supply in multiple plate-and-frame heat exchangers, which also operate in parallel. PCW is then filtered (15 µm nominal) and distributed to the process areas at 65°F and 85 psig. Operating conditions at Qimonda are typical of the IC industry as a whole. While most PCW systems are designed for a 10°F delta temperature, they operate at a 3° to 5°F delta.

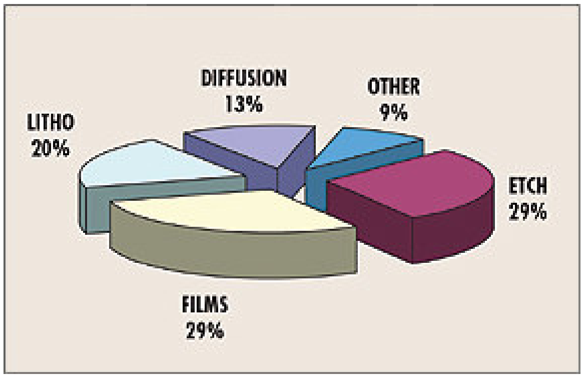


Figure 12: PCW use per process type.

The system is designed to generate return water with a temperature of 75°F. Although a review of the system's operating conditions revealed that recirculation flow was 120% of design capacity, heat rejection by the heat exchangers was only 60%. Hence, the temperature of the water returning from the distribution loop was less than 70°F.

To illustrate the importance of understanding equipment utility requirements, it is useful to consider a typical temperature control unit. Process cooling water requirements provided by equipment vendors typically specify only a required flow rate. However, that flow is often based on a conservatively high water supply temperature that may or may not appear in the equipment literature. Figure 13 shows the required PCW flow versus supply water temperature for a typical temperature controller. According to the literature, flow should be 3.5 gal/min with a water temperature of 85°F. But based on the actual PCW operating temperature, a flow of 1.5 gal/min is sufficient for heat rejection. In short, the required flow is less than 50% of that specified in the vendor literature. While an additional 2 gal/min of cooling water may seem trivial, the impact is significant when multiplied by the number of temperature controllers in a typical IC fab.

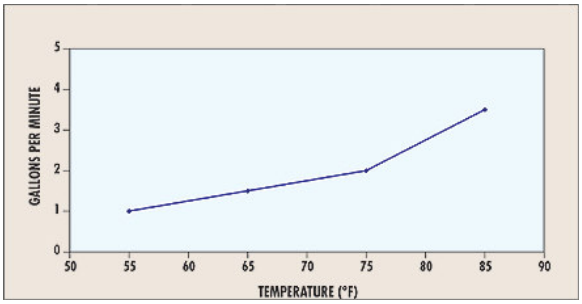


Figure 13: Required water flow versus temperature.

The fab's approach to PCW conservation was similar to that used for CDA conservation. First, site usage data were reviewed to identify the areas with the highest consumption and the most common PCW applications. Together with the project objectives, the tool and applications list was reviewed with area representatives. The system design criteria were compared with tool-vendor specifications, after which a field review of tools was performed to compare use rates on similar equipment. Based on these reviews, three problems emerged:

- Vendor requirements were based on higher inlet PCW temperatures than those generated by the system.
- Equipment flows exceeded vendor requirements.
- Equipment outlet PCW temperatures were significantly lower than system design criteria.

The last of these problems was the most difficult to identify because the hookup lines between the tool and the PCW system typically contain instruments for monitoring flow and pressure, but not temperature. Opportunities for improvement were prioritized based on the anticipated flow reduction, the risk to production, potential cost savings, and the required investment.

The first task identified by the review was to lower the amount of cooling water consumed by tool process vacuum pumps. The original flow specification was based on an inlet temperature higher than the site's PCW system supply temperature. In addition, flow rates observed in the field often exceeded the manufacturer's requirements. Working closely with vendor representatives, Qimonda engineers established new flow requirements based on actual site PCW temperatures. This collaboration also revealed that requirements for identical pumps could be different depending on tool process conditions and pump duty cycles.

The vendor representatives adjusted the process vacuum pumps to accommodate lower PCW flows while closely monitoring pump operating temperatures. The work was coordinated with the manufacturing areas, and in some cases tools were idled to avoid damaging production wafers. After the adjustments were made, pump temperatures were monitored as part of routine maintenance activities.

Although the average flow reduction at each pump was small, the modification had a significant overall impact, because many pumps were involved. In fact, reducing the amount of cooling water consumed by several hundred vacuum pumps has had the largest effect on utility savings to date, decreasing recirculation flow by 480 gal/min.

This type of conservation effort faces several challenges. First, obtaining flow versus temperature information from manufacturers can be difficult and time-consuming. In such cases, it may be possible to calculate flow rates if the required heat removal is known. In other cases, the information can be determined empirically. For example, field surveys identified many identical systems that operated at different flow rates. Unable to obtain detailed temperature versus flow information, the engineers decreased the flow rates incrementally to achieve the proper levels.

Equipment design, if it precludes operation below a certain flow rate, can pose another obstacle. For example, some equipment uses preset flow sensors either in place of or in addition to temperature sensors to monitor insufficient cooling conditions. In order to satisfy the equipment's internal alarm device, PCW flow may have to be maintained above the level actually called for in the specifications.

Another challenge is time and commitment. The type of effort required to conserve process cooling water prevents equipment personnel from tending to production needs. This is likely the reason why most PCW systems operate well below their design temperature differential (supply temperature minus return temperature).

Qimonda's PCW conservation efforts were primarily driven by the avoidance of capital investment. The reductions achieved to date have enabled the deployment of new production tools without the need to install additional pumps (and their associated power, piping, and controls). PCW conservation activities have reduced recirculation flow by 500 gal/min, or 8% of the initial system recirculation flow. And as with the CDA system, eliminating the need for additional system capacity by reducing PCW consumption has saved the fab $250,000 in capital expenditures and $60,000 in operating costs.

Since the successful completion of the process vacuum project, other types of equipment have undergone conservation measures, including cryogenic compressors and temperature control units that support various production tools. An ongoing effort, this work should result in further utility reductions over time.

Conclusion

The competitive DRAM market requires smaller, higher-capacity devices at a lower cost per bit. Optimizing process utilities at Qimonda has helped to decrease operating and production costs, lowering the amount of capital investment required to increase production output and accommodate technology changes.

In general, the conservation efforts described in this article are not complicated. However, they do involve a thorough understanding of process utility costs and applications, careful assessment of potential opportunities, and an almost tedious approach to implementation. The fab's experience—the reduction of site operating expenses by more than $1 million a year—indicates that these activities have a favorable payback. Process utility optimization efforts clearly represent a valuable, largely unrealized opportunity.

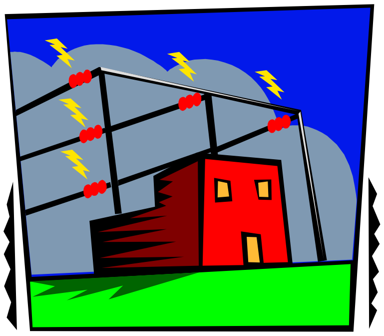
About the Authors

Wayne Curcie is a senior engineer at Qimonda in Richmond, VA, where he has worked for nine years. He has been responsible for exhaust systems, bulk and specialty gases, and quality assurance and quality control. Previously, Curcie was a project manager and lead process engineer at IDC. He also worked at IBM for nine years as a UPW and wastewater-treatment-systems engineer. He has published and presented several articles related to semiconductor process support systems. He received a BS in chemical engineering from Syracuse University in Syracuse, NY, and is a member of the American Institute of Chemical Engineers. (Curcie can be reached at 804/952-7880 or wayne.curcie@qimonda.com.)

Kenneth Hill is a cleanroom support group leader at Qimonda in Richmond, VA, where he has worked for eight years. He has cleanroom certification and room-integrity responsibilities and oversees the testing and balancing of all exhaust systems, air-handling units, and process tools throughout the facility. (Hill can be reached at 804/952-6854 or kenneth.hill@qimonda.com.)

Billy Jones is the contamination control specialist at Qimonda in Richmond, VA, where he has worked for eight years. Previously, he was a service engineer at Flanders Filters, where he built, tested, and certified cleanrooms and containment housings and devices for the nuclear, biological, chemical, pharmaceutical, and semiconductor industries. Jones is a member of the Institute of Environmental Science and Technology, the Electrostatic Discharge Association, and the International Technology Roadmap for Semiconductors yield enhancement, wafer environment contamination control working group. (Jones can be reached at 804/952-6817 or billy.jones@qimonda.com.)

Leo Meire is a process engineer at Qimonda in Richmond, VA, where he is responsible for waste treatment systems and several wet utility systems (including UPW and PCW). He has nine years of experience in the semiconductor industry. Previously, he was a systems engineer at a nuclear power plant. He has published several articles in industry magazines related to water treatment. A member of the American Society of Mechanical Engineers, he received an MS in mechanical engineering from the University of Virginia in Charlottesville and holds a PE license in the state of Virginia. (Meire can be reached at 804/952-6102 or leo.meire@qimonda.com.)



SEMICONDUCTOR TRIVIA

20 years ago, AMD introduced the first 1 megabit EPROM.

The first hand held electronic games (Mattel Football) were programmed at Rockwell Microelectronics Division using modified MOS-FET handheld calculator chips.

NIST was twice listed in the Guinness Book of World Records for the highest frequency measured.

In 1970, W.S. Boyle and G.E. Smith described a new type of imaging detector consisting of an array of conductor-insulator-semiconductor capacitors. This new system, called a charge coupled device (CCD) stored charge in electronic potential wells formed on the surface of a semiconductor chip…now you know where all those digital cameras came from.

In 2005 the integrated circuit industry consumed about 20,000 metric tonnes of raw polysilicon. If the raw polysilicon were loaded in railroad cars, it would require two trains of 120 cars each. That amount of raw polysilicon produced enough wafers to cover the surface of 768 football fields.

In 2005, the semiconductor industry made over 90 million transistors for every man, woman and child on Earth, and by 2010, this number should be 1 billion transistors.

EquipmentFutures™ Report Sees Robust Semiconductor Equipment Sales Decelerating More Rapidly than Previously Forecast

Quarterly equipment sales projected to slow to single-digit cumulative growth rate by mid-2007

SANTA CRUZ, Calif. – August 16, 2006 – While suppliers of production equipment to the chip industry have enjoyed a strong demand for their wares over the past several years, the latest quarterly EquipmentFutures™ report sees previous double-digit sales growth rates quickly decelerating to a single-digit rate sooner than previously forecast.

The quarterly updated forecast offered by Strategic Marketing Associates (SMA) and Wright Williams & Kelly, Inc. (WWK), projects annual sales growth to decelerate to about a 5.0 percent rate by mid-2007 followed by a more attractive cumulative growth rate of about 17 percent per year over the next four years. Distinguishing itself from other industry forecasts, EquipmentFutures takes into account not only semiconductor and equipment sales but also end market demand.

"Although June quarter equipment sales were up nearly 60 percent compared to the same quarter a year ago, we anticipate a more rapid deceleration to single-digit sales growth by mid-2007," said George Burns, SMA president. He noted that the semiconductor industry continues to follow historical cyclical growth patterns dating back to 1976, adding that current market research still supports equipment sales strengthening by mid-2008 as chip makers add production equipment required to support the most advanced process technologies.

EquipmentFutures Report

The report is structured to track six individual equipment groupings, namely: lithography, chemical mechanical polishing (CMP); etch & clean; implant & thermal processing; metal deposition; and non-metal deposition. The just updated outlook reports:

- Of the six equipment groupings tracked, all will continue to grow over the five-year forecast but at a lower rate.
- Flash memory content in consumer electronics will be a primary growth driver for the semiconductor industry.
- Consumer electronics is forecast to grow at an average annual growth rate of about 19 percent over the next five years, over a percentage point higher than the average annual growth rate forecast for equipment sales.

According to Daren Dance, WWK vice president of technology, "Our quarterly outlook offers an essential strategic planning tool for suppliers of production equipment and materials as well as chip makers. Financial analysts who need to track leading market indicators in the semiconductor industry can also benefit from this unique set of reports." He noted that the impact of the International Technology Roadmap for Semiconductors (ITRS) and other market considerations are included as important inputs to the forecast. Subscriptions to the quarterly EquipmentFutures Report may be ordered though the SMA website.

In addition to jointly producing EquipmentFutures, SMA and WWK individually publish other timely information products that are pertinent to the semiconductor industry. SMA offers several Excel spreadsheets updated quarterly, including its flagship FabFutures™ Report that details expenditures for more than 200 wafer fabs historically and over the next 6 quarters. WWK publishes "Applied Co$t Modeling™" – a quarterly newsletter focused on the application and use of cost modeling tools and related topics.

About Strategic Marketing Associates

Strategic Marketing Associates is the semiconductor industry's leading market research company focused solely on the wafer fab. Since 1992, SMA has provided its subscribers with comprehensive and accurate data about all aspects of the fab business plus insight on key trends. SMA provides a suite of information products covering wafer fabrication costs, fab capacity, technology, products, locations and closure plans. Additionally, Strategic Marketing Associates has compiled the industry's most comprehensive and advanced fab database, World Fab Watch, that features a complete listing of the world's fabs and their characteristics. SMA reports are widely read by semiconductor manufacturers, equipment and materials companies, fab construction companies and financial analysts. For more information, visit http://www.scfab.com.

Simulation Assisted Scheduling with Factory Explorer®

Jani Jasadiredja and Daren Dance, Wright Williams & Kelly, Inc

The ultimate objective of scheduling is "to deliver on time". Analysis of a schedule requires detailed information from several sources — the process flow has to be very accurate and the current combination of products, lot locations, cycle times and dispatch rules has to be understood. Information on equipment setups, recipe changeovers, pilot wafer strategies, and metrology sampling plans is also important. With this information, simulation assisted scheduling can be used to predict where the lot is going to be after a certain time. If the future location of the lot meets delivery requirements — you have a good schedule. If not, then the schedule needs to be revised.

By a strict definition of the word ‘scheduling,’ simulation is not a good scheduling tool. In other words, FX output will not tell you what lot to start next. Simulation is a good tool for managing and manipulating the data required for successful simulation assisted scheduling. Further, an FX simulation assisted schedule analysis includes the variability of “daily life”. Given a schedule, FX can simulate what the outcome will be based on the current information and processing sequences that you have defined. This becomes very useful in day to day practice.

Many companies use spreadsheets for scheduling analysis. However, a spreadsheet has difficulty reflecting the realities of “daily life” in the factory on a schedule. Equipment breaks down, operators get sick or go on vacation, or the critical component gets misrouted and is delivered late.

Simulation can be handy for catching resource interaction constraints; take for example the case where several tools all have slack capacity and are served by an operator group with spare capacity. Due to the way lots come due for loading/unloading, the net result can be a constraint because one operator can't be in two places at one time. Thus, benefit of that slack capacity is lost. That is something you can see from the simulation but is very hard to capture in a spreadsheet[6].

In a current implementation, FX has been used in this manner to test schedules from a capacity viewpoint. In this FX implementation, the schedule is based on the product demand for the next time period. Then using FX, bottlenecks are identified which may limit the capability to deliver on time. Some of the bottlenecks might include:

- Equipment capacity or availability
- Labor resources, including skills and availability
- Materials or component deliveries

Based on this simulation assisted scheduling analysis, the user implements changes to address the resource bottlenecks. Changes might include:

- Additional capital allocation for bottleneck tools
- Adjusting works hours or staffing level requirements
- Increasing material or component inventories
- Outsourcing for additional capabilities
- Eliminating low-margin products from the product mix

This implementation has been very successful using FX as a simulation assisted scheduling analysis tool and has developed support for using these methods from high level management.

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[6] Dr. Frank Chance, Private Communication, 18 Sep 2006

Another implementation was to understand the ramp-down schedule of a product in a factory. In this case, an FX simulation was used to determine when the last lot would be out of the factory. The user then used FX to experiment with different product start schedules to expedite the ramp down.

Our thoughts on using simulation as scheduling tool come from the "Toyota Production System" thought process. This is often called "Lean" Manufacturing:

- Know your capacity
- Manage the bottleneck tools and near bottleneck tools
- Eliminate sources of variation
- Eliminate excess inventory that hides sources of variation
- Figure out what needs improvement

We use FX with simulation assisted scheduling to simulate the impacts of changes in inventories, dispatch rules, equipment capacities, resources and schedules. If you understand and mitigate the roadblocks inherent in your schedule, then you don't have any problem delivering on time.

How do you do scheduling right now? What is the output that you look at? How do you reschedule to accommodate change, interruptions, and variability? The objective of simulation assisted scheduling is not to change your way of scheduling but to provide a tool to help you schedule your operations to maximize your profitability.

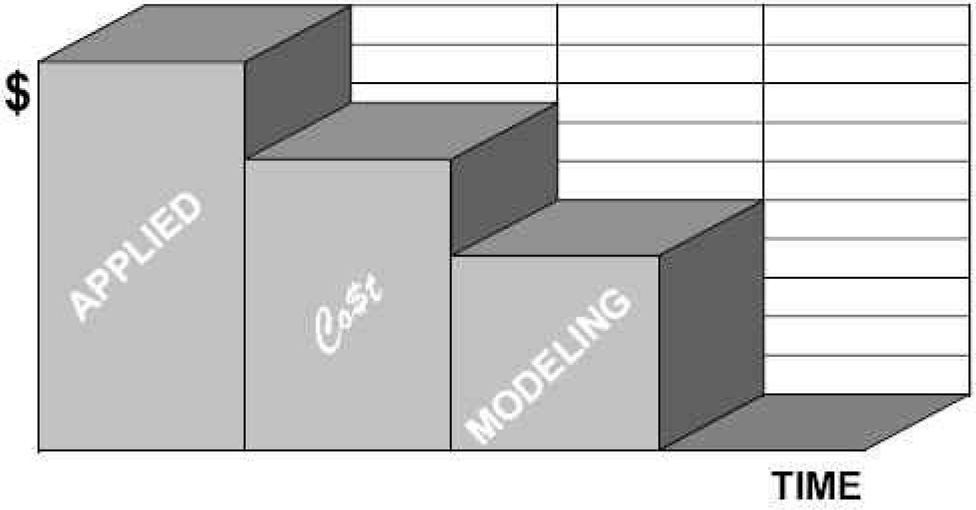
WWK Software Version List

Listed below is the current version release for each of WWK's software products:

TWO COOL® v3.1.5
PRO COOL® v1.1.3 (both Process Sequence and Sort/Test)
COOLSoft™ v2.0.1
COOL FUSION™ v1.0
Factory Commander® v3.1.3.09
Factory Explorer® v2.8.6

TWO COOL® v3.1.6 is expected in the next 30 days and will include updates for widescreen displays and increased digits to the left of the decimal for some inputs.

Factory Explorer® v2.9 will be released in the next month and will include major enhancements for alternate operator groups and schedules.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