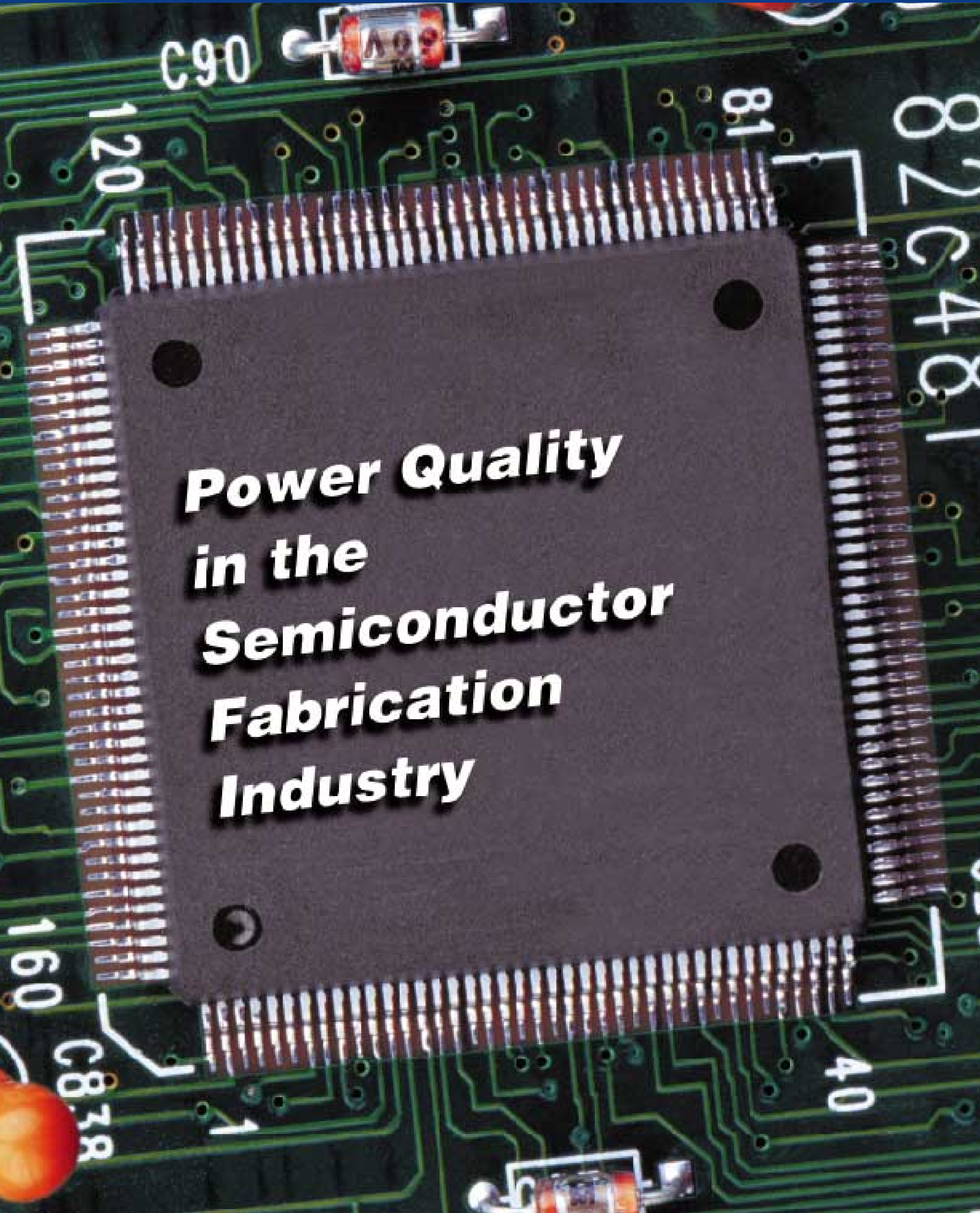
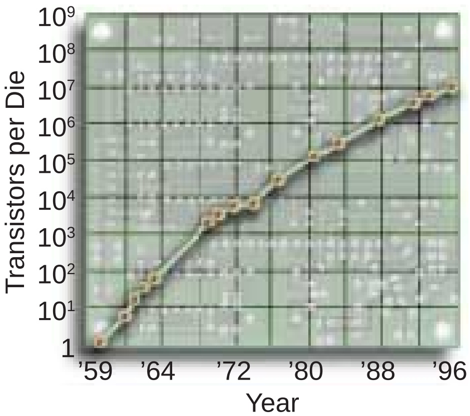
EPRI Power Electronics Applications Center ◆ System Compatibility Research Project



Power Quality in the Semiconductor Fabrication Industry

Integrated Circuits

Moore's Law



In 1965, Gordon Moore, then director of R&D at Fairchild Semiconductor, predicted an astonishing rate of increase in IC density. Accepted now as "Moore's Law," this highly accurate forecast gives the world a window into a future of integrated circuits packed with billions of transistors and exquisite features. Moore attributed the steady increase in IC density to innovations in photolithography and other IC-rendering processes, which require tools controlled by the very items they are designed to process—integrated circuits. The logic circuits of these tools can render the tools susceptible to changes in the supply voltage, a significant drawback to the industry's indispensable compliance with Moore's Law.

They are everywhere. In computers, of course, but also in cars, wrist watches, greeting cards, and pacemakers. The industrialized world has been enamored with the integrated circuit since the mid-1960s, when the first appliances fortified with microscopic circuits hit the market. Back then, each integrated circuit contained fewer than one hundred transistors. Today, an integrated circuit packs up to ten million transistors on real estate smaller than a postage stamp. In fact, the component density of integrated circuits has been doubling every year-to-eighteen-months since the first planar transistor was innovated in 1959, a trend known as Moore's Law.

The rush toward faster-smaller-better and greater yields has engendered an industry dependent on a constant evolution of manufacturing technologies. Clean rooms, micro-precision tools, and sophisticated photolithographic processes are the norms of the modern semiconductor-fabrication plant, which may cost over a billion dollars to construct. To stay competitive, most semiconductor manufacturers operate their automated fabrication tools continuously—twenty-four hours a day, 365 days a year. This unparalleled reliance on automation equipment has compelled the semiconductor-fabrication industry to evaluate the compatibility between fabrication tools and the electricity that powers them. The challenge to both the semiconductor-fabrication industry and the electric utility industry is to explore power quality issues to ensure the reliable operation of fabrication tools during common and often unavoidable electrical disturbances.

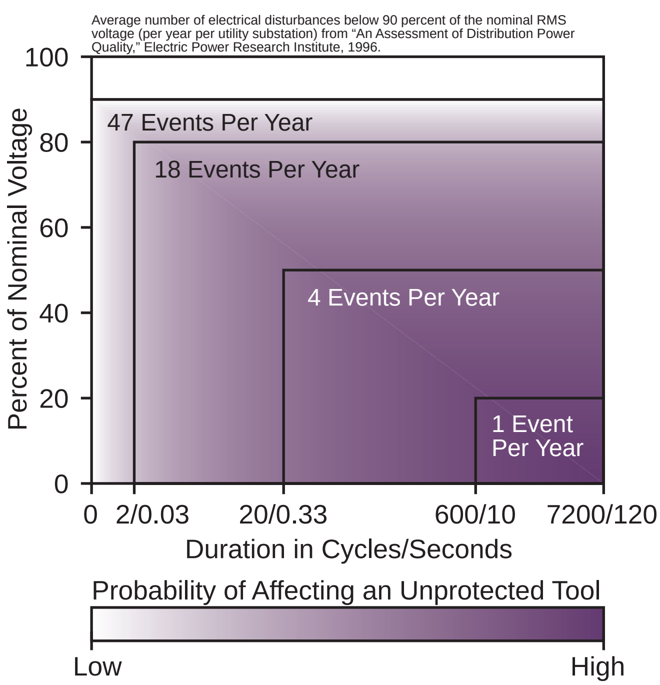
The Consequences of Tool Incompatibility

Less than forty years old, the semiconductor-fabrication industry is still experiencing growing pains. Among the adversities the industry faces are clashes between the increasingly advanced technologies required to create integrated circuits and an electrical environment subject to the whim of nature, accidents of man, and routine utility activities such as capacitor switching. When fabrication tools do not operate properly in their intended electrical environment, the consequences can be quite costly. "The ultra-precise processes of the semiconductor industry are a good example," say Vladi Basch and Tom Key in *Power Value Magazine*, "where millivolts of electricity and microns of mechanical motion determine the destiny of a 100-billion-dollar industry." Bearing the burden of increasing circuit density and decreasing line widths, fabrication tools rely on continuous, disturbance-free power to carry out their intended operations. Yet even common electrical disturbances may corrupt their performance. For example, a "minor" voltage sag to eighty-five percent of nominal voltage for only eight cycles (about 133 milliseconds) may be enough to shut down certain tools, interrupting high-precision processes and possibly damaging many in-process silicon wafers. With each silicon wafer containing several hundred individual integrated circuits valued at hundreds of dollars each, it's not hard to imagine a million dollars in damaged goods, as well as hours or even days to restart and qualify sensitive fabrication tools.

Power Requirements of Semiconductor Fabrication

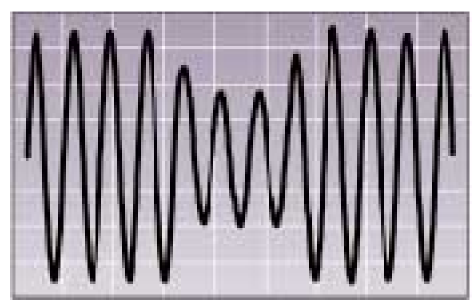
The design, construction, installation, and operation of semiconductor-fabrication tools require a convergence of many disciplines, including physics, chemistry, electronics, chemical engineering, optical engineering, process engineering, and control engineering. The tolerances of most processes in the fabrication of integrated circuits are unforgiving. For example, wafer processing requires precise temperature control with a miserly tolerance of plus-or-minus 0.5 degrees Fahrenheit and plus-or-minus five percent relative humidity. When a fabrication tool operates without interruption in its intended electrical environment, it is said to be *immune* to common electrical disturbances. However, modern fabrication tools—most of which are controlled by electronics such as microprocessors—are extraordinarily sensitive to electrical disturbances.

In their quest to understand and prevent electrical disturbances, electric utilities have been monitoring their power lines for decades. As shown in the graph below, electric utilities use the data from power quality surveys to suggest a benchmark for equipment immunity. The goal of the electric utility industry is to help process industries ensure compatibility between equipment and the electrical environment, not purvey perfect power. For the high-precision tools of the semiconductor-fabrication industry, little information about tool-performance standards and the quality of power can be gleaned from standards organizations. The immunity of information-technology equipment is well addressed by the Information Technology Industry Council, but no standards organization specifically addresses the immunity of fabrication tools. On the power side, American standards allow the nominal steady-state voltage at the point of use to vary continuously between eighty-seven and 106 percent. Yet no standards address the common voltage sags, voltage swells, and momentary voltage interruptions that are responsible for most process interruptions.



Voltage Sags and Momentary Voltage Interruptions

The most common and consequential electrical disturbance affecting vulnerable fabrication tools is the voltage sag. In fact, a voltage sag is eight to ten times more likely than a complete power outage. Voltage sags are defined as a decrease in voltage amplitude lasting less than three seconds with a remaining voltage of at least ten percent, while momentary voltage interruptions have no remaining voltage.



A Three-Cycle Voltage Sag to Fifty-Eight Percent of the Nominal Voltage

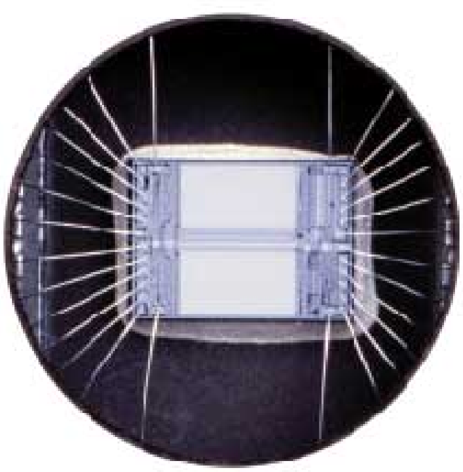
Voltage sags and momentary interruptions are usually caused by a remote fault somewhere in the power system—the result of lightning, downed or crossed power lines, or the failure of power-distribution equipment. Voltage sags may also be caused by the normal operation of facility equipment such as large motors. Sags and interruptions can cause fabrication tools to shut down or malfunction, both of which can result in damaged products and lost production time.

Challenges in the Chipmaking Industry

The Black and the Red: Tool compatibility affects the bottom line of process industries.

"The ultra-precise processes of the semiconductor industry are a good example, where millivolts of electricity and microns of mechanical motion determine the destiny of a 100-billion-dollar industry."

—Vladi Basch, Baltimore Gas & Electric, and Tom Key, the EPRI Power Electronics Applications Center



To reconcile the strict power requirements of automated processes and the realities of the electrical environment, semiconductor manufacturers are investing significant capital in protecting fabrication equipment from electrical disturbances. They are evaluating power-monitoring software, modifications to tool controls, and power-conditioning equipment. By declaring a need for compatible tools, they are recognizing the importance of building immunity into automation equipment, a process that has been maturing in other process industries since the 1980s.

Computer modeling enables design engineers to simulate the performance of fabrication tools before a prototype is actually built. Yet power quality, in most cases, is not one of the process variables factored into the tool model, even though semiconductor manufacturers report power-related shutdown as a frequent cause of process disruptions. Industrial processes that rely on electronics-based technologies will experience equipment-compatibility problems in a typical electrical environment. The big difference between the chemical-batch processes of the wafer-processing industry and the processes of other industries is that wafer processing allows limited opportunities to check work in progress.

To process a single multilayer wafer can take months, and damaged wafers may continue to be processed for weeks until quality-control personnel discover the problem. In extreme cases, an electrical disturbance can result in the loss of up to an entire week's worth of production and scrapped products. In most other process industries, automation equipment can be restored within a few minutes to a few hours after an interruption, resulting in limited down time. However, some fabrication tools such as diffusion furnaces, etchers, and mask aligners require many man-hours to set up and qualify. Days of wafer production can be lost requalifying these tools.

Wafer processing does have one advantage over other process industries. Rather than set up shop in existing buildings—which may house the seeds of potential power quality problems such as faulty or inadequate wiring—chip manufacturers tend to build new facilities. Therefore, the industry greatly benefits from modern wiring and grounding practices, as well as building structures tailored to particular activities. However, profitable semiconductor manufacturing—even in immaculate facilities—can be jeopardized by the introduction of unfamiliar and untested manufacturing equipment. Even equipment tried and true in other industries may pose incompatibility risks in the relatively new and complex environment of a modern semiconductor-manufacturing facility.

Automated Processes and Fabrication Tools

"Nowhere on earth—or in space—will you find more sophisticated positioning control equipment than in semiconductor manufacturing," says John Gyorki, editor of *Machine Design*. Most of the automated processes of the semiconductor-fabrication industry, such as servo-driven robots used for high-precision manipulation, are controlled by sensitive microprocessors. The wafer manufacturing facility of the 21st century, already envisioned by design engineers, will be even more rich in complexity. Eight-inch wafers will be replaced by twelve-inch wafers, fulfilling expectations for a linear increase in wafer size that follows Moore's Law. In turn, wafer surface features will decrease in size, perhaps shrinking to 0.2 microns by the turn of the century. Facilities will crank out as many as 500 five-layer wafers per day. Tools such as plasma etchers and chemical vapor-deposition systems may be controlled by computers akin to neural networks. But enthusiasm for these technological triumphs will certainly be compromised by actual *in situ* performance unless existing and potential tool compatibility problems are addressed today.

Not all power quality problems in the semiconductor-fabrication industry can be attributed to vanguard technologies. Tried-and-true devices such as the ubiquitous switch-mode power supply may trip off-line during electrical disturbances common to the electrical environment of a wafer-manufacturing facility. And the simple relay—an ancient technology compared to today's electronic marvels—has been identified as the Achilles' heel of many process industries, including semiconductor fabrication. The following sections describe the various wafer-manufacturing processes that rely upon a vast array of automation tools and control devices, and the various power quality concerns associated with those processes.

Wafer Cleaning

At the beginning of wafer processing and at various times during processing, wafers must be thoroughly cleaned. The wafer cleaner, called a "wet tool," uses deionized water to clean up to a hundred wafers at a time in a single process vessel. If the wet tool shuts down, restarting it at the exact point in the process where it shut down can be complicated and time-consuming. When a wet tool is used as an etcher, a shutdown may cause wafers to be overprocessed by the etching acid, resulting in irrevocably damaged wafers.

Spin Coating

After the wafers are cleaned, they are treated with an adhesive promoter to enable a layer of photoresist to adhere to their surfaces. A uniform layer of photoresist is then applied by microprocessor-controlled spin coaters, giving the wafers characteristics similar to a piece of photographic paper. Any voltage fluctuations or unstable control voltage can cause an uneven coat of photoresist, which may degrade the circuit image. Infrared, conduction, or microwave heaters then soft-bake the wafers to vaporize any residual solvents. If any solvents remain on wafer surfaces because of a tool shutdown or malfunction, image transfer from the image mask to the photoresist will be inferior.

Thunderstorm Warning

In the spring and summer, thunderstorms can emerge within a matter of minutes from a clear blue sky. Semiconductor manufacturers know all too well that thunderstorms mean lightning, and in most parts of the world, lightning means voltage sags and momentary interruptions. To brace its entire facility against the threat of an approaching thunderstorm, one semiconductor manufacturer maintains its own early warning system called "Storm Scope." Any threat of a thunderstorm compels the manufacturer to shut down 130 fabrication tools. In the four hours it normally takes 30,000 wafers to be transported from one tool to the next, the facility waits out the storm with only partial, slow production, perhaps losing half a million dollars worth of revenue, but perhaps heading off an even greater loss of revenue and scrapped wafers caused by an uncontrolled, sag-induced shutdown.

Tool Attention

In the past, it was quite common to install engine-generator sets and enormous macro-scale uninterruptible power supplies to protect an entire manufacturing facility against voltage sags. However, power quality investigations of modern manufacturing facilities have suggested a better, much more cost-effective approach. By installing power-conditioning devices at only the sensitive parts of each fabrication tool, the cost of power conditioning is not wasted on the more robust parts. Power conditioners such as uninterruptible power supplies, constant-voltage transformers, and stored-energy inverters are used to power critical devices and circuits during voltage sags and momentary interruptions. Perhaps the next generation of fabrication tools will integrate such power-conditioning devices as a standard feature.

Photolithography

Photolithography requires precise temperature control and therefore takes place in temperature-controlled chambers. In these chambers, step-and-repeat aligners position wafer sections under masks of the circuit image, and portions of the photoresist are exposed to ultraviolet light. The steppers must precisely control process parameters such as alignment of the submicron image on the wafer, energy output, and duration of exposure. After exposure, wafers are sprayed or washed in a developer to remove the exposed portion of the photoresist. A microprocessor controls the concentration, temperature, and application time of the developer.

If any subsystem of the photolithographic process shuts down, the entire system must be restarted and requalified, and any wafer that was exposed during the shutdown will have to be reworked, which involves stripping the photoresist, recoating the wafer, and re-exposing it to the circuit image. When temperature-control devices malfunction, the temperature may rise or fall below the limits set for the enclosed photolithographic tools, resulting in lenses contracting or expanding beyond their specifications, altered image sizes, or distorted images. Optical tests must then be performed to determine how the temperature change affected the tools.

Etching

Etchers remove the semiconductor layer that was exposed during the photolithography process, and strippers finish the job by removing the remaining photoresist. Etching duration and uniformity, vessel temperature and pressure, and concentration of the etching material—whether liquid or gas—must be precisely controlled. If the etcher shuts down during the etching process, wafers must be examined to see how much etching was completed and how much more remains. The parameters of the control software, such as etch rate, may have to be modified to finish the partially etched wafers. Incomplete removal of the photoresist may result in subsequent wafer defects. Sag-sensitive tools and controls in the etching process include emergency-off circuits, vacuum-pump controls, and microprocessors that control the entire process.

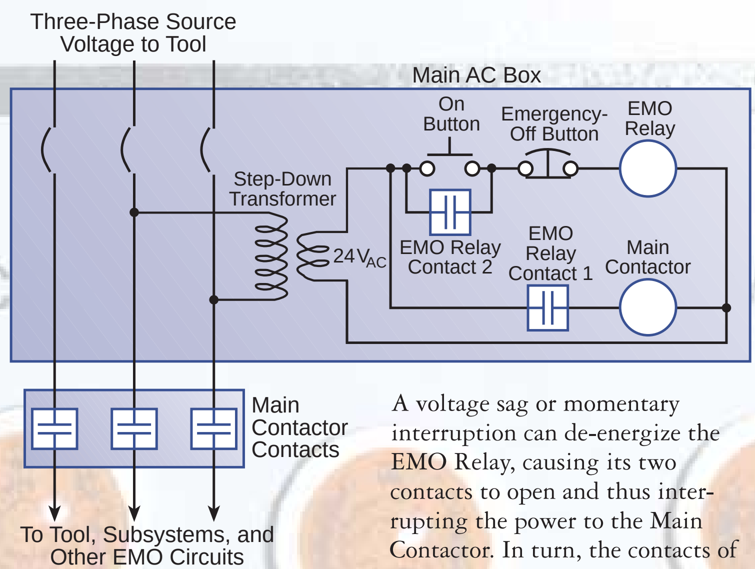
Deposition

Deposition of chemicals and silicon dioxide is the most exacting stage of semiconductor fabrication. Under carefully controlled conditions, wafers are heated and exposed to ultra-pure oxygen in diffusion furnaces, which "grows" an insulating layer of silicon dioxide on the surfaces of the wafers. "Windows" between layers are etched away, and metal is deposited to fill the windows and form electrical connections between layers. During these repeated steps, opportunities abound for power-related shutdowns and malfunctions.

To ensure safety, semiconductor fabrication tools have emergency-off circuits that, when activated, shut down a fabrication tool or one of its subsystems. In the most common electrical connection, the emergency-off (EMO) circuit derives its power from two lines of the three-phase voltage through a step-down transformer such as a 208-to-24-volt transformer. As shown in the figure below, the EMO circuit contains a single-phase relay (EMO Relay) and a three-phase contactor (Main Contactor), which are energized when the On Button is pressed, thus connecting the fabrication tool, its subsystems, and other EMO circuits through the Main Contactor Contacts.

The EMO circuit has been identified as one of the most vulnerable parts of fabrication tools. Field investigations and laboratory testing have revealed that EMO circuits can shut down a tool during voltage sags as minor as eighty percent of the nominal voltage and lasting only two cycles. If the plant voltage is low or the output of the step-down transformer is lower than the rated voltage of the relays and contactors, an EMO circuit will be even more susceptible to voltage sags.

To remedy the sensitivity of EMO circuits, a power conditioner can be installed on the primary side of the step-down transformer connected to the EMO circuit. Effective power conditioners for this application include uninterruptible power supplies, constant voltage transformers, and stored-energy inverters. Note that the use of such power conditioners does not make the fabrication tool less responsive to emergency shutdowns initiated by pressing an emergency-off button.



A voltage sag or momentary interruption can de-energize the EMO Relay, causing its two contacts to open and thus interrupting the power to the Main Contactor. In turn, the contacts of the Main Contactor interrupt the power to the tool, its subsystems, and other EMO circuits. The result: total shutdown of the tool, requiring a manual restart of the tool by pressing the On Button. Even if the EMO Relay is robust enough to withstand a voltage sag, the contacts of the Main Contactor may chatter during such a sag. These chattering contacts translate a sag into momentary voltage interruptions as they contact and break. The EMO circuits incorporated into subsystems such as the temperature-control unit, vacuum pumps, the tool controller, and the tool chamber may interrupt power to the subsystems. The result: discrete shutdowns of the various subsystems—increasing the potential for wafer damage.

Power Conditioners

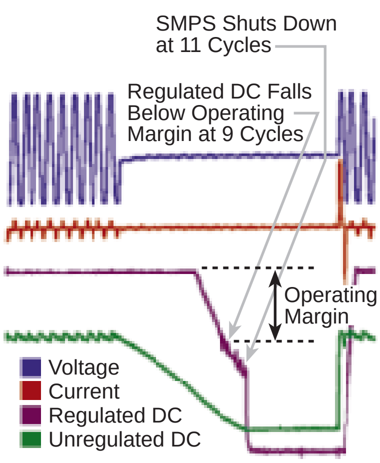
*An **uninterruptible power supply** contains batteries and a switching circuit to provide power to a fabrication tool during voltage sags and momentary interruptions. The batteries can provide power for minutes, enabling a fabrication tool to ride through even brief power outages.*

*A **constant-voltage transformer**, also called a ferro-resonant transformer, regulates the power without switching to an alternate power source. It contains no stored energy and therefore is much less effective than an uninterruptible power supply during momentary voltage interruptions.*

*A **stored-energy inverter** provides an alternate source of power to the fabrication tool much in the same way an uninterruptible power supply does. However, it uses capacitors—not batteries—for its stored energy, which lasts only up to one second.*

The Switch-Mode Power Supply: Part I

Many fabrication tools, especially the vast majority that use microprocessor controls, are powered by switch-mode power supplies, or SMPSs. These power supplies are more efficient and lighter than linear power supplies, but their superior ability to ride through voltage sags and momentary interruptions depends greatly upon the amount of energy storage they have in the form of inductors, capacitors, or both: The more storage, the greater the tolerance to voltage sags and momentary interruptions.



This figure shows what happens when the power to an ordinary SMPS is interrupted for a brief period (eighteen cycles, or 300 milliseconds). The unregulated DC voltage begins to decline almost immediately after the onset of the interruption. After about nine cycles (150 milliseconds), the regulated DC falls outside the operating margin of the logic circuits of a fabrication tool.

The microprocessor-controlled tools used during deposition include diffusion tubes, epitaxial reactors, ion implanters, and CVD reactors. If any of these tools are upset or shut down by a voltage sag, the wafer may be destroyed. For example, the heat-exchange system may shut down, causing the temperature inside the deposition chamber to rise. The platen heaters, which would likely continue to operate, may overcook wafers—which must then be scrapped—or contaminate the wafers—which would require additional cleaning in a wet tool.

Wafer Sort

Before a completed wafer leaves the clean room, it goes through "wafer sort," a complex electrical test that checks the functionality of each IC on the wafer. Over 10,000 circuit checks per second are performed by needle-like probes that contact test points on the wafer surface. These probes move from one circuit to the next until the entire wafer has been examined. Integrated circuits that do not pass the tests are marked with ink for rejection. A tool shutdown or malfunction at this point could result in retesting circuits or circuits being mismarked.

Assembly

Next, scribers score and dicers cut the wafers into individual chips, and the inked chips are discarded. A high-precision wire-bonding machine then attaches lead wires a fraction of the width of a human hair to the leads of the remaining chips. To precisely guide the wires to the IC pads, wire-bonding machines use high-performance servo controllers and a vision system. Finally, the chip is encapsulated in a package for protection, ready for final test and delivery to the customer. Any tool shutdowns or malfunctions during assembly may result in faulty wire bonding, which, if not discovered before encapsulation, may render the chip unusable.

Ensuring Tool Compatibility

By supplying manufacturing facilities with higher voltages, limiting the length of distribution feeders, and reducing the number of other industrial customers connected to the same distribution lines, utilities have been successful in reducing the exposure of their industrial customers to common and expected electrical disturbances. Facility managers and equipment engineers are learning ways to reduce electrical disturbances that originate from within a facility, such as separating large motor loads from sensitive equipment, filtering harmonic currents, and ensuring proper wiring and grounding of equipment. To protect their exacting processes from voltage sags—to "sag-proof" their production of integrated circuits—semiconductor manufacturers also use various power-conditioning technologies. But the process engineer standing over a scatter of defective wafers understands that more must be done.

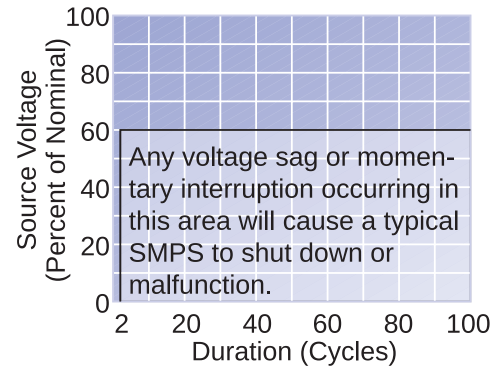
Semiconductor manufacturers can prevent this scene by participating in a formal initiative to resolve tool compatibility problems. The Power Electronics Applications Center (PEAC), the Electric Power Research Institute (EPRI), its member utilities, semiconductor manufacturers, and tool manufacturers are participating in a System Compatibility Research Project to develop performance criteria and test procedures to:

- ♦ Characterize fabrication tools.
- ♦ Explore ways to enhance tool immunity to electrical disturbances.
- ♦ Determine the most cost-effective power-conditioning solutions to mitigate the effects of electrical disturbances.
- ♦ Encourage manufacturers of fabrication tools to address immunity.

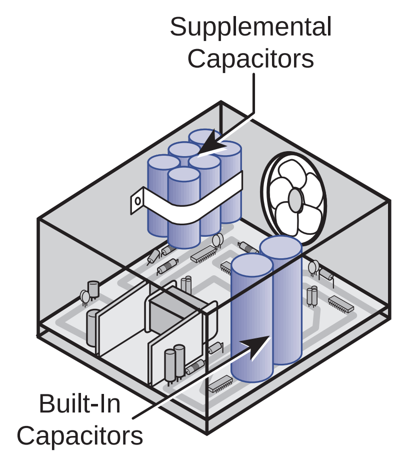
Perhaps more than any other industry, the semiconductor-fabrication industry demonstrates the need for tool and process characterization, by which the electrical characteristics of an entire system are disclosed and its components analyzed as they work together in their intended electrical environment. Because many chipmaking facilities are similar, a study of a few will benefit most, making the results of this project applicable to the entire industry. Additionally, many fabrication tools and their components can be isolated and tested in the laboratory to determine their tolerance to voltage sags and momentary interruptions. The information resulting from such activities will greatly benefit tool manufacturers, just as similar information has benefited the designers of other process equipment such as adjustable-speed drives.

One inherent benefit of this work is that many of the lessons learned during the current era of the eight-inch wafer will likely be applicable to the new tools designed to process twelve-inch wafers. For example, the power supplies of the new tools will probably be similar to those of the current generation of tools, and control circuits such as emergency-off circuits will endure practically unchanged. Thus semiconductor manufacturers and electric utilities can leverage today's experience to anticipate tomorrow's power quality issues. The electric utility industry also looks forward to enhancements of the electric system, based upon what it has learned about the unique electrical requirements of its high-tech customers.

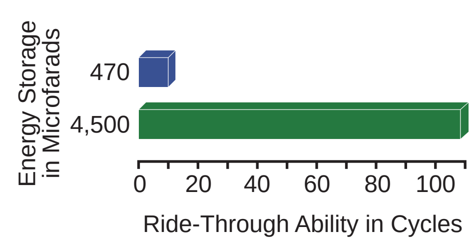
The Switch-Mode Power Supply: Part II



Tests conducted at the EPRI Power Electronics Applications Center have demonstrated that increasing the energy storage of an SMPS by adding capacitors will increase its tolerance to voltage sags and momentary interruptions proportional to the increase in capacitance.



With an increase in energy storage from 470 to 4,500 microfarads, the ability of an SMPS to ride through a complete interruption of AC voltage was extended from 10.5 cycles (175 milliseconds) to 108 cycles (1.8 seconds).



Most high-precision, microprocessor-controlled fabrication tools are sensitive to electrical disturbances.

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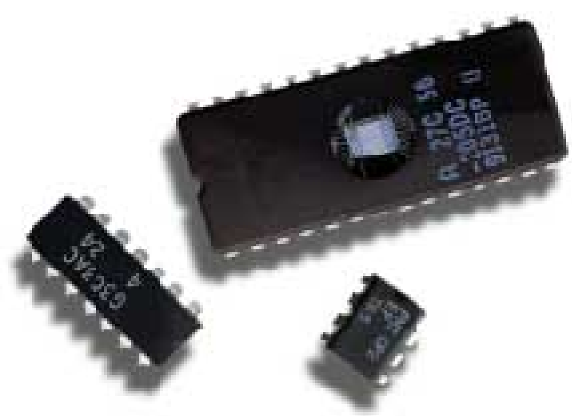


Case Study: The Wet Tool

Working with the vendor of a wet tool, engineers from a semiconductor facility, two electric utilities, and the EPRI Power Electronics Applications Center conducted a comprehensive power quality investigation of a wet tool with a history of shutdowns. The investigation team first determined the effectiveness of an uninterruptible power supply (UPS) already installed on the sensitive components of the wet tool. Using the Process Ride-Through Evaluation System developed by PEAC, the engineers injected voltage sags of various durations and magnitudes into the voltage input of the wet tool during normal operation. Voltage sags between ninety-five percent and fifty percent of the nominal voltage were injected on each phase of the three-phase voltage, then two phases, and then all three phases.

With the UPS disconnected from the wet tool, components of the wet tool shut down during voltage sags to eighty percent of the normal voltage and lasting as few as five cycles (about eighty-three milliseconds), but only when the two phases supplying the emergency-stop circuit were sagged. With the UPS connected, the wet tool did not shut down during any of the sag tests.

The heart of the wet tool is a sonic cleaning system that modulates crystals to transfer waves of energy to wafers submerged in a bath of water. Because the cleaning system was considered immune to voltage sags, it was not connected to the UPS during the original UPS installation. Testing this part of the wet tool confirmed that the cleaning system did not shut down during voltage sags. However, the magnitude of the sonic waves did decrease in proportion to the depth of the applied voltage sag. Further research of this phenomenon must be conducted to determine how such wave attenuation affects the cleaning process. In the meantime, the power quality engineers recommended connecting the sonic cleaning system to the UPS.

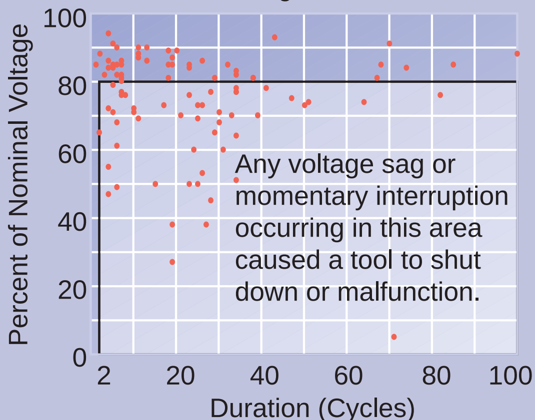
Case Study: The Etcher

A semiconductor-fabrication plant was exposed to many voltage sags originating in the power distribution system. Concurrently, various fabrication tools would shut down—particularly an etcher tool—resulting in damaged wafers. Four years of recorded electrical disturbances on the utility side of the meter confirmed that voltage sags were causing the shutdowns. The tool vendor installed a UPS to condition the power to the twenty-four-volt power supply of the etcher's input/output logic circuits and computer control. However, the shutdowns continued. The semiconductor manufacturer therefore initiated a power quality survey of its facility, with a goal for the etcher to tolerate sags to seventy-percent of the nominal voltage for one second.

Engineers from the semiconductor manufacturer, tool vendor, local electric utility, and the EPRI Power Electronics Applications Center conducted an investigation of the etcher tool. The Process Ride-Through Evaluation System was used to inject voltage sags of predetermined durations and magnitudes into phase-to-neutral, phase-to-phase, and then all phases of the three-phase voltage supplying the etcher. During the tests, the critical parts of the etcher connected to the UPS and all emergency-off (EMO) circuits were closely monitored.

Figure A shows the four-year distribution of voltage sags that in some way affected the manufacturer's fabrication tools (sags are indicated by red dots). Also in Figure A is the tolerance curve of the entire etcher system. Note that although the UPS was installed to protect what were considered the most critical components of the etcher tool, those components still shut down during a two-cycle sag to eighty percent of the nominal voltage. The EMO circuits were suspected as a weak link in the etcher system. The EMO circuit for the twenty-four-volt power supply and computer controller was powered through a step-down transformer that was connected to the power system ahead of the UPS.

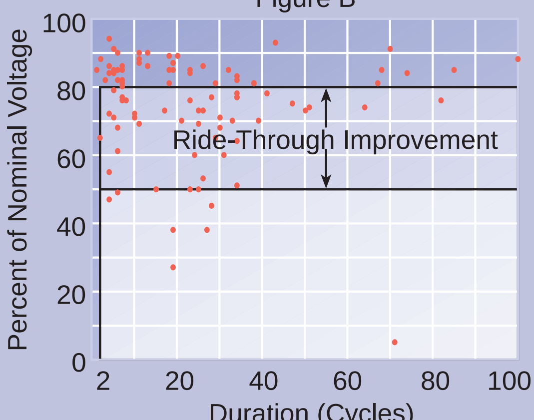
Figure A



To improve tool compatibility, the EMO circuit was moved to the output of the UPS and a four-kVA stored-energy inverter was connected to the main AC box and the vacuum pumps. Figure B shows the resulting twenty-five-percent increase in sag tolerance.

Despite this significant improvement in sag tolerance, two new components of the etcher tool—a turbo pump and a temperature-control unit—continued to shut down at sixty-five percent of the nominal voltage or less. The power quality engineers recommend connecting these two sensitive components of the etcher tool to the stored-energy inverter. By "sag-proofing" the various components of the etcher tool, the entire tool would be able to ride through voltage sags at least to fifty percent of the nominal voltage, which was the limit of the Process Ride-Through Evaluation System.

Figure B



Process Ride-Through Evaluation System

The EPRI Power Electronics Applications Center offers diagnostic services to the semiconductor-fabrication industry in the laboratory and the field. The star diagnostic tool is a device that helps power quality engineers diagnose incompatibilities between fabrication tools and the electrical environment. Officially dubbed the Process Ride-Through Evaluation System but less formally referred to as the porto-sag, it can induce voltage sags in the voltage supplying fabrication tools as they operate in their normal environment. A computer precisely controls the magnitude and duration of the sag, and it monitors up to sixteen process parameters to determine the voltage tolerance of the tool. Such precise monitoring is often necessary, especially when eyewitness accounts of process interruptions don't illuminate cause and effect.

Task 24: System Compatibility in the Semiconductor Fabrication Industry
Task 24 is just one of many EPRI initiatives to resolve compatibility in the process industries. The scope of this task will be determined by participating semiconductor manufacturers and sponsoring electric utilities. Semiconductor manufacturers will provide technical information to help identify differences between the typical electrical environment in a semiconductor-fabrication facility and the voltage tolerance of fabrication tools. Industry consultants will provide expertise on the characteristics of fabrication tools. Tool manufacturers will provide current-technology samples to test.

The benefits of the task will be far-reaching. The results of Task 24 will enable sponsoring utilities to evaluate industry expectations in the context of their service capabilities. Sponsoring semiconductor manufacturers will receive information about improving the compatibility between fabrication tools and the electrical environment. Participating tool manufacturers will be better able to design products that meet the tool-compatibility requirements of their customers. And participating designers and consultants will be better able to identify the "real-world" power and tool needs of the semiconductor industry.

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Electric Power Research Institute
Electricity is increasingly recognized as a key to societal progress throughout the world, driving economic prosperity and improving the quality of life. The Electric Power Research Institute delivers the science and technology to make the generation, delivery, and use of electricity affordable, efficient, and environmentally sound.

Created by the nation's electric utilities in 1973, EPRI is one of America's oldest and largest research consortia, with some 700 members and an annual budget of about $500 million. Linked to a global network of technical specialists, EPRI scientists and engineers develop innovative solutions to the world's toughest energy problems while expanding opportunities for a dynamic industry.

EPRI. Powering Progress

Power Electronics Applications Center
The Power Electronics Applications Center (PEAC) is a power quality research center of the Electric Power Research Institute (EPRI), whose mission is to discover, develop, and deliver advances in science and technology for the benefit of electric utilities, their customers, and society. In 1986, EPRI established PEAC to facilitate the widespread and practical use of power electronics technologies. Since its inauguration, PEAC has evolved into an international power quality resource for electric utilities and their customers, providing services essential to the success of electric utilities:

- Supporting electric utilities in their efforts to understand and resolve power quality problems and system compatibility issues.
- Enabling utilities to solidify durable, beneficial relationships with their customers, equipment and appliance manufacturers, and standards organizations.
- Empowering utilities with the knowledge required to financially thrive in a new world of competition and deregulation.

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