Improving Throughput and Yield Rates Through Digital Transformation

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By digitalizing processes, semiconductor manufacturers can monitor operations in real time, identifying and responding to issues before they can slow or shut down production.

WITH THE GLOBAL CHIP SHORTAGE predicted to continue, wafer production is top of mind. To meet demand, construction started on 19 new semiconductor fabrication plants in 2021 worldwide with another 10 set to break ground this year. Once operational, the new fabs will have the potential to manufacture up to 2.6 million wafers per month (in 200 mm equivalents). While achieving high wafer throughput and yield rates is the goal of most fabs, yield and reliability issues can arise.

As wafer fabrication plants age, machines may deteriorate, leaks can occur and resource use may fluctuate. If an issue slows or stops production, it can cost a fab millions of dollars. To remain competitive and profitable at this time of unprecedented demand, some fabricators are digitally transforming their businesses, relying on the Industrial Internet of Things (IIoT) to monitor the condition of their machines in real time and optimize their manufacturing processes.

From digitization to digital transformation

Digital transformation is a term that's used a lot, but what does it really mean? Digital transformation is a process that a facility, system or piece of equipment undergoes that allows end users to see real-time data, make decisions on the data and act based on those decisions. It's preceded by both digitization and digitalization. Digitization is the transformation of analog information into digital information, while digitalization is the transformation of processes using digital technologies and digital information.

In a fab, those terms translate this way: Personnel may still manually check pressure ranges using a pressure gauge and clipboard. This is analog information. Replacing that pressure gauge with a sensor that transmits pressure range information into a computer is digitization. If the collected information just remains as data points, it won't mean anything, but if that information is translated into a story about the process that operators can use to make decisions, that's digitalization. For example, slow changes in pressure typically aren't noticed using analog information until wafer quality or productivity levels change. Through digitalization, operators can see minute pressure changes as deviations from the baseline and quickly address them before they impact quality or production.

Figure 1. Digitalization makes it possible for human operators to have a conversation with their machinery, providing real-time insight into manufacturing processes. *(Source: iStock)*

Figure 2. The digital transformation of semiconductor wafer fabrication can ensure transparency, precision and accuracy in each step of the manufacturing process, improving efficiency and productivity. *(Source: iStock)*

When all processes within a fab have been digitalized, it has been digitally transformed.

Ultimately, digital transformation is about taking pragmatic steps to make manufacturing processes clearer, easier and more tangible, as well as getting the right information into the hands of the right expert at the right time. It isn't just about collecting data; it's using that data to tell a story and using that story to take appropriate action (FIGURE 1). Digital transformation can improve the speed and accuracy of decision-making, which, in turn, can improve overall efficiency and productivity as well as lower costs (FIGURE 2).

The beginning of any digital transformation journey starts with baseline data. For a new fab, baseline data is vital; however, established fabs with no historic data will also gain significant benefits. Reliable and accurate baseline resource data provides a point of comparison that manufacturers can use to detect and resolve process and equipment issues if they arise. Preventing issues before they happen minimizes downtime and keeps production moving.

There are many resources, including electricity, water, gas and chemicals, that are consumed in the semiconductor processes used to manufacture integrated circuit chips. Chip manufacturers can use a combination of sensors, a reliable network and data analytics to generate baseline data on resource use for each process step. Data from continuous monitoring can then be compared to that baseline data.

The pressure, temperature, vibration or flow of a process medium are just some of the different parameters that can be measured. Any anomalies that differ from baseline data can indicate that there is an issue. By having a more comprehensive picture of processes and the operation overall, operators can quickly identify the root cause of an issue, make informed decisions and take specific action rather than go through a lengthy troubleshooting process.

With the potential for fabs to achieve a high level of speed and accuracy, it's hard to say exactly why digital transformation hasn't already been more widely adopted in semiconductor fabrication. It's possible that the industry is yet to understand the given opportunities that come from transitioning from analog to digital information and how to leverage digitized data from all process stages. This, however, makes it a great opportunity for fabs to become part of the momentum and lead through the innovation of business applications and models.

Reducing downtime and improving safety through preventive maintenance

Many corrosive, flammable gases and chemicals are used in wafer manufacturing, including hydrogen sulfide, hydrogen bromide and tungsten hexafluoride. These can be dangerous to people and machinery that come in contact with them, causing physical harm, process issues and/or equipment failure. Having a clear, real-time story about machine health can help protect personnel and equipment through preventive maintenance.

Preventive maintenance is a proactive approach to maintenance that uses real-time data about the health and condition of fab assets to make informed, preemptive maintenance decisions. By servicing assets before issues can arise, fabs can minimize or eliminate issues that lead to unplanned downtime.

To begin practicing preventive maintenance, fabs can digitize the maintenance points of a process and measure those parameters. Then, operators will begin to receive live data into their network and can interpret each data point of their processes with analytical data. This predictive data will allow operators to foresee the state of equipment and when it's approaching the end of its serviceable life.

Without a clear picture of asset health, a machine or component requiring maintenance may go undetected until bigger issues, such as corrosion and leaks, occur. When that happens, fabs may have to stop production to troubleshoot. Then, a human operator must identify the problem and its location and place an order for maintenance.

This manual, reactive approach can extend the issue, rack up downtime and place a human operator into closer proximity with toxic gases. Compare this to an operator who remotely receives a notification that maintenance is required for a specific component, then immediately places the maintenance order for personnel (or, to stay remote, a machine) to perform the service during planned service periods. In this way, preventive maintenance powered by digital transformation can shorten the process, improve safety and minimize unplanned downtime.

As another example, let's consider

Figure 3. High-purity regulators, like Emerson's TESCOM™ 64-2600 Series Electropolished Pressure Regulator, are used for semiconductor applications that require high cleanliness rates, low leakage and precise pressure control. *(image courtesy of Emerson)*

preventive maintenance of gas cabinet systems. This is an area where highly corrosive gases can be found and corrosion can lead to leaks. Any kind of leakage from a gas cabinet system can contaminate the whole system. By integrating sensors in a gas cabinet system, the sensors can measure specified parameters, such as excess flow, and the software that sensors feed this data can predict or determine the early stages of a leak.

Using data from sensors translated through the software and applications, an operator will be able to remotely detect whether corrosion, and resulting leaks, is happening. Say they receive a notification that a specific regulator has reached the end of its life cycle. By identifying that root cause, personnel can perform preventive maintenance, replacing the component before the leak can grow and affect production.

It should also be noted that the quality of the regulators used in gas cabinet systems can also affect throughput and yield rates. To optimize production, it's important to source regulators customized specifically for semiconductor applications. These ultra-high-purity regulators are made from materials that resist corrosion when exposed to hazardous media and have seals with low leakage rates (FIGURES 3-5).

The fab of the future

Once all wafer manufacturing processes have been digitalized, a fab can say that it has undergone complete digital transformation. At this stage, human operators take on a supervisory role and all processes are performed by a computer. When

Figure 4. Emerson's ER5000 Series Electropneumatic Actuator is a microprocessor-based proportional, integral, derivative (PID) controller that provides precise algorithmic pressure control and, when connected to any pneumatically actuated regulator, can help fabs move toward automation. *(image courtesy of Emerson)*

components that have reached the end of their serviceable life must be replaced, a computer can generate the work order, a human operator can approve it and maintenance can be performed by an automated machine.

This level of automation and precision can be made possible by a digital transformation solution such as a digital twin. Digital twins are digital replications of a company's actual assets that are entirely capable of imitating any human intelligence resource with little to no operative errors. For example, a digital twin that is constantly learning from the data it receives from a gas cabinet system will improve decision-making over time, identifying and addressing leaks earlier or even predicting them before they can happen. Such high-level accuracy and quick action keep personnel who directly manage the corrosive gas application site safe, potentially eliminate downtime and optimize throughput and yield rates.

While a digital twin isn't always necessary, it's one of the most popular digital transformation solutions

Figure 5. Gas cabinet systems depend on the precise control that regulators, like Emerson's TESCOM 64-2800 Series Electropolished Pressure Regulator in 4-port option, provide to store hazardous media safely and efficiently for use within semiconductor manufacturing systems. *(image courtesy of Emerson)*

available today. Whether a fab should integrate that technology or not depends on the fab, its goals and its budget.

Both new and established fabs can start or further their digital transformation journey at any time. While those journeys may look different from one another, there are some similar foundational steps. First, fabs need to identify what their priorities are. Do they want to start by digitizing their bulk specialty gas storage or clean room data? Or do they want to digitize the entire manufacturing process at once?

Once a fab has identified its priorities, it can identify what kind of means and what kind of digitization the analog data will go through. From there, it can move to digitalization and interpret and analyze that raw data it's mining.

The good news is that no fab must take these steps alone. To identify the best solutions for its goals, it's important that a wafer manufacturer finds a partner with a comprehensive suite of technologies who can support it through its solution-finding journey and seamlessly deploy tactics.

Digital transformation and solution providers, such as Emerson, can work one-on-one with manufacturers to customize and deploy a solution with a facility's unique requirements in mind. An expert provider can offer both sensing technology and a comprehensive, easy-to-read multimedia analytics dashboard that makes the machine-human conversation simple to understand.

Conclusion

The digital transformation of semiconductor manufacturing is coming. There is an opportunity right now for fabs to build that future, understand their opportunities and move from analog operations and mindset into digitalization. Once manufacturers start speaking with their machines, they may find the conversation flows with ease and, ultimately, reaps many valuable benefits. Fabs can improve safety and employ preventive maintenance, achieving a level of operational precision and accuracy that can ultimately optimize throughput and yield rates to meet the market's demands today — and tomorrow.

About the Author

Julia Villa is a product marketing manager at Emerson. She has five years of experience in the industry, managing products from concept to completion. She received a Bachelor of Science in chemical engineering from Tecnolgico de Monterrey and later earned a master's degree in marketing from EGADE Business School.

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case scenarios. Such scenarios could include attaching and removing a film from a device comprising one or more weakly bound coatings or could utilise multi-films in device designs where one or more films form part of the final device such as for conductive tracks and contacts embedded in an electrical isolation layer or a 3D electrical contact via. The SFL technology and film consumables can be custom designed and manufactured to provide ease of implementation in new or existing R&D and manufacturing applications. Processing hardware in the form of entry-level desktop tools, standalone systems, or integrated workstations can be configured and constructed to meet application-specific requirements.

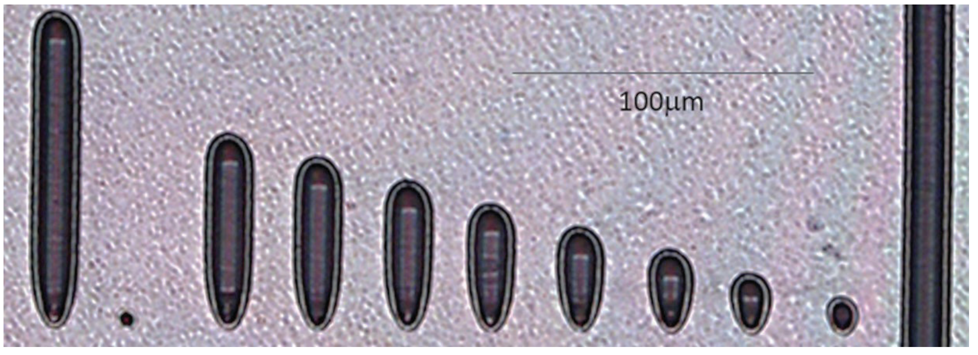

Figure 3. A polyester film processed using a focussed spot violet laser diode, here a melt ridge is present.

This exciting emerging alternative to photolithography and other aperture-masking patterning methods for low temperature deposited coatings used in electronic and photonic device fabrication, is a key enabler for low cost, environmentally friendly, flexible manufacturing for many conventional and novel R&D, prototyping, and production applications. With applicability across manufacturing technologies for SMD components, semiconductors, flexible hybrid electronics, disposable paper electronics, microfluidics, thin film sensors, smart packaging, and flexible ICs, that are used in applications including rigid and flexible displays, wearable electronics, electronic glazing, electric automobiles, energy generation and conversion, and the Internet of Things, Solid Film Lithography has a bright future.

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