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Fab transformation: Four markers of excellence in wafer production

To succeed with their lean initiatives, managers should focus on improving plant uptime, equipment utilization, process variability, and product quality.

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Achieving excellence in complex semiconductor manufacturing environments is difficult. The chip-fabrication process involves numerous, nonlinear steps and stages, and it requires advanced technologies that must be deployed in ultraclean environments that are expensive to set up and maintain. Demands from clients can change quickly—a car manufacturer may want to switch to a different type of chip in its vehicles, integrating that component into its production lines within two months. Plants must be able to continually adjust their production recipes, schedules, and priorities to accommodate these new requests.

To crack the code of excellence, some semiconductor companies have tried implementing lean principles, with varying levels of success. The core concepts behind lean programs are well established and fairly straightforward. But as many semiconductor players have learned, the application of lean principles on the shop floor is much more complicated than it seems. To successfully modify some of the most advanced and difficult production processes in the world of manufacturing, managers and equipment operators must show full dedication to the change effort, but that focus can be hard to maintain when there is pressure to improve performance immediately and when both managers and employees are skeptical about proposed process changes.

We have found that refocusing lean efforts on four critical dimensions of plant operations—uptime, utilization, process variability, and product quality—can provide a jumpstart. To increase the odds of maintaining process improvements over the long term, managers should also establish a culture that relies on data analysis, problem solving, and cross-functional collaboration. One large manufacturer of eight-inch silicon wafers that adopted this approach was able to increase its output by more than 25 percent and decrease its cycle time by 20 percent. The team at this fab did not need to invest in more equipment or increase its head count to achieve these goals. Instead, fab managers systematically reviewed plant processes and behaviors and, in response to their findings, adopted new, lean practices. In this way, they were able to improve equipment reliability and uptime, work-flow management, plant agility, and product quality. The company sought to re-create itself as a lean organization—and its investment in this pursuit showed significant returns within 18 months.

Let's take a closer look at what we'll call Fab X, the challenges it faced, and the actions it took to improve operations—actions other semiconductor companies may be able to emulate.

Facing production challenges

Fab X was seeking to increase its moves per day—the number of times a wafer advances from one step in the manufacturing process to the next—but, for a variety of reasons, activity was stalled below target. Plant leaders had publicly stated their desire to adopt a lean approach and improve the company's efficiency and effectiveness, but that philosophy was not reflected on the shop floor.

A close assessment of operations at the semiconductor plant revealed that there was no shared understanding among managers across the plant of where bottlenecks were occurring, and there was too little time spent conducting timely, detailed analyses of overall equipment effectiveness, given the work in progress. The lead team was more likely to try to find a temporary fix for a faulty machine so it could meet a weekly production quota, rather than task a team to explore root causes of the problem and get rid of it once and for all. Every project was "urgent"; too many work streams and activities were being launched at the same time, with limited or no time allotted to appropriately assess outcomes. Managers did not prioritize projects, nor did they monitor quality in any systematic way. So cycle times increased while volumes decreased.

Meanwhile, a detailed look at the organization overall revealed there was little communication among senior managers situated in a shop that was hierarchical in nature. The senior leaders were technicians with deep knowledge about product and equipment specs, and they valued that form of organizational capital above all else. They failed to recognize the importance of gathering input on the production process from all levels of the plant and across functions and were missing the signs that employees were confused about the performance feedback they were being given and the direction in which the plant was going. Managers did not see the long-term advantages of creating an inclusive work environment that would engage employees and establish a culture of continuous improvement. The resulting low morale contributed to decreased productivity.

Focusing on four markers of excellence

Fab X's experience was not unique; these are the perennial problems for the industry. Oversight of complex enterprises requires a very high level of expertise in production and line management, equipment maintenance, process and production engineering, and quality control. But Fab X was able to turn around its fortunes by optimizing its performance in the four critical areas of plant operations mentioned earlier.

Uptime. All fabs tend to experience two main production delays—when machinery goes offline for scheduled repairs, and when it shuts down unexpectedly. To address the former, Fab X introduced a new scheme for planning equipment maintenance based on advanced analytics. After the production of a certain number of wafers, cleaning must take place. The information managers were using to determine the optimal time for this changeover had been incomplete—different units collected and recorded the information using different methods. Fab X now uses sensors and tags embedded in its equipment to collect data that can then be run through various simulations—asking, for instance, what will the impact be if we take down a high-temperature furnace on nights and weekends or at certain hours? The plant is also relying more heavily on tried-and-true lean production methods such as the single-minute-exchange-of-die process, which emphasizes quick change of parts used at various stages in the manufacturing process—altering the sequence of part replacements, for instance, or automating various replacement steps. In the case of unscheduled outages, Fab X recognized it could not necessarily plan for every shutdown possibility, but managers did implement structured problem-solving sessions focused on figuring out exactly what went wrong. Previously, senior managers would have spent the time justifying among themselves what happened rather than trying to fix it. By contrast, their daylong discussions of root causes—which involve fab managers and representatives from across all functions—have allowed the fab to realize an almost 70 percent reduction in equipment downtime (both scheduled and unscheduled).

Utilization. Another production-cost challenge for fab managers is minimizing standby, or the time a machine tool is available for use but not actually in operation. Tools that are perpetually in standby mode can cost the plant thousands of dollars per minute. At most plants, managers may try to address production shortfalls by investing in more tools, even though the existing ones are being underutilized, or firing and then hiring new line staff, hoping they will do things differently. Fab X was able to increase the utilization of tools in its plant by combining quantitative and qualitative research to redesign work flows, redeploy existing staff, and standardize certain shop-floor activities. To determine the right number of people needed to operate each piece of equipment in each of its production bays, for instance, managers shadowed shop-floor operators, recorded their observations, and discussed their findings with shift leaders and operators. The critical part of this process was collecting feedback from the operators and convening team discussions to foster continuous improvement. In these discussions, fab managers learned that handoffs between operators on a given tool and between operators handling different parts of the fabrication process were a big time sink. So they considered the optimal times required for shift changes, breaks, and other shop-floor activities that were indirectly related to production. Based on these data, managers standardized their transfer activities and created schedules that allowed them to allocate the right resources at just the right times. Through its efforts to calculate staffing needs from the bottom up and reallocate operators more effectively, Fab X was able to reduce its standby times by 70 percent.

Variability. Fab managers must maintain a careful balance in work flow. One small bottleneck in the wafer-production process can throw off lead times and performance across the entire plant. To better manage the work in progress, leaders at Fab X assessed equipment utilization rates and cycle times, and identified several machines that, given their history of outages, alarms, and operator issues, had the potential to become huge bottlenecks as demand increased. Just as they had in their uptime analysis, the fab managers convened root-cause discussions, pulling in representatives from different functions—for instance, production, engineering, maintenance, and quality control—to assess the critical reasons for variability among some of the machines and to develop a plan for boosting overall equipment effectiveness. As a result of their collaboration and analysis, the Fab X team revised the dispatching rules associated with the challenged equipment—for instance, requiring the system to deliver a wafer faster or immediately—and took other steps to increase capacity. Through these efforts, the plant was able to minimize bottlenecks, improve its overall work flow, and reduce its overall cycle-time variability by up to 15 percent.

Quality. Often fabrication plants seeking to increase production and reduce cycle time believe that they will need to make small sacrifices in quality to do so. This is false; process improvements do not need to come at the expense of quality. Lean principles applied to improve manufacturing operations will indirectly affect the quality of the semiconductors being produced. To diminish the effects of chronic quality issues, managers at Fab X focused on identifying core process and product flaws. A critical point for shop-floor personnel was to identify errors where they are generated and not at the end of production, when other components have already been added to a cracked wafer. To do so, fab managers compared the process steps during which errors typically happened with the process steps during which errors were actually found and were able to differentiate between the early leaks in error detection, the chronic process issues that led to product flaws, and those errors that could have been avoided through root-cause analysis. (The data were drawn from the process information the plant routinely collected as part of its operations.) As a result of these findings, the plant has increased its yield and, over time, has gradually decreased its waste.

Developing lean teams and capabilities

Fab managers cannot realize the same sort of improvements in uptime, utilization, variability, and quality that Fab X did without having the right team and infrastructure to implement and support a shop-floor transformation. They must create an environment that emphasizes data analysis, problem solving, cross-functional collaboration, and execution.

Fab X introduced new tools and technologies—for instance, data-visualization tools and software applications that would assist in the daily tracking of key performance indicators, procurement decisions, and other process parameters. The plant also reorganized its leadership structure to include a core "lean team" whose primary activity in the fab was to oversee efficiency efforts. That team, many members of which were steeped in technical rather than "soft" skills, underwent a series of workshops focused on developing competencies in coaching, planning, conflict management, and delivering and receiving feedback, among other things. The sessions involved role playing and one-on-one interactions. Additionally, another 100 employees, at different levels of the company, were trained as change agents for lean transformation, so not all the change was top down. This focus on improving the health and sustainability of the organization is ongoing, so it is still too soon to quantify the overall effect of the company's lean transformation, but Fab X has been identified within the industry as a best-practice plant.

Interviews with employees and operators at Fab X before managers there undertook a lean transformation suggested that they understood the need for change—the lag in performance was apparent—but different constituents within the plant held different beliefs about why the change needed to happen. And while all agreed that cross-functional collaboration was crucial, none felt that top management had made this a priority in its day-to-day operations. In post-transformation discussions with employees, the same respondents reported a shift away from competition among functions and shifts; clearer "rules of the road," with a reduction in the number of key performance indicators to just several crucial ones; less focus on firefighting and more feedback sessions involving people from all levels of the fab; and a robust, data-oriented approach to monitoring results and modifying processes. "The distance has closed between us and senior leaders," one operator noted.

Fabs that want to achieve lean transformation can similarly use surveys, interviews, and feedback sessions to build awareness among employees about the need for performance improvement, to educate them about lean principles and approaches, and to ensure that there is sufficient appetite and willingness to embrace this sort of change. This is not an easy or a short exercise; without a change in organizational mind-set, it can be difficult to sustain a lean program over the long term.

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The production processes and activities associated with semiconductor fabrication are highly volatile and very complex, and applying lean principles in these environments can be difficult. But as Fab X learned, significant performance improvements are possible when companies train their lean efforts on four main areas—uptime, utilization, variability, and quality—and develop a corporate infrastructure that supports this focus. The fabs that do can reduce downtime and waste, increase cycle time, and improve the quality of their products over the long term. o

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