Performance Gains through Automation

Automation Now Mission Critical as Manufacturers Focus on Maximizing Fab Output

High utilization has returned to the semiconductor manufacturing industry, and with it, all the challenges associated with achieving the most output at lowest cost. Tool-based approaches focus on solutions that improve tool unit output (wafers/day) through excursion control, process control (Cpk), and throughput enhancements. Fab-wide approaches focus on using automation to improve throughput and optimize cycle time. In this article, we survey both approaches, and offer our insight into future trends.

IMPROVING TOOL PRODUCTIVITY

Critical modules like photolithography have had automated process control for quite some time in order to control overlay and critical dimensions. As manufacturing complexity increases, we are seeing automated process control proliferate to other modules. And, manufacturers today are moving beyond process control to real-time excursion control. This reduces the impact of excursions and reduces tool downtime caused by corrective and preventive maintenance. Real-time monitoring of key tool parameters is rapidly becoming a standard mode of operation. Applying models against these key parameters lets manufacturers:

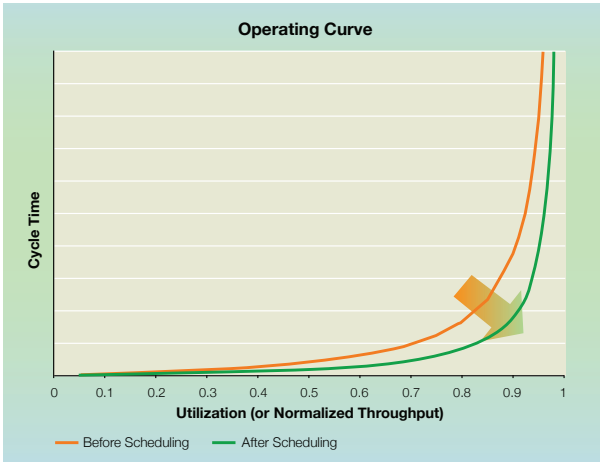
- Reduce mean time to detect excursions.
- Identify drift of key tool parameters to predict potential excursions.
- Identify mismatched parameters between tools and chambers.
- Implement run-to-run process control to modify process recipes to correct for drift.

The data required for excursion control also gives manufacturers a bonus: visibility into their tools' operational performance. This allows them to optimize process recipes, identify white space that can be eliminated to increase throughput, and perform chamber-to-chamber and tool-to-tool comparisons for chamber and tool matching.

Many semiconductor manufacturers now find that maintaining good yields and avoiding excursions as they transition to 45nm and below is more difficult than it was when shifting to 65nm. This is because the process windows for 45nm are smaller and device performance and yields are more sensitive to minor variations in processing conditions. Previously, the tool and process variation could be controlled through point solutions or systems that relied on manual monitoring and intervention. To provide satisfactory and predictable yields at 45nm, many manufacturers plan to extend their point solutions for equipment control and advanced process control to fab-wide solutions. Most, however, find that existing solutions tailored to a few critical areas do not scale to a large number of modules, much less the entire fab.

FAB-WIDE THROUGHPUT IMPROVEMENT AND CYCLE TIME OPTIMIZATION

As wafer starts and utilizations increase, manufacturers cannot respond in the short-term by purchasing capital equipment to increase capacity. They have to find new ways to maximize output from their existing capacity. Traditionally, advanced dispatching rules have been used to increase fab throughput without compromising cycle time. But today, many manufacturers have reached the limits of what they can do with dispatching systems that focus only on lots currently in queue. Some are experimenting with advanced scheduling, with a special emphasis on short-interval scheduling. This approach offers the benefit of being able to look at both upstream and downstream WIP simultaneously and take it into consideration when developing run plans. In addition, manufacturers can employ scheduling



▲ **FIGURE 1.** Fab Operating Curve.

algorithms to produce schedules that are nearly optimal for a given set of conditions. The resulting schedules reduce overall variability associated with running a tool set or fab and shift the operating curve as shown in Figure 1. Short-interval scheduling particularly benefits areas of the fab with batch tools (diffusion, wet clean) and constraint tools (typically lithography tools).

FUTURE TRENDS

Automation solutions for semiconductor manufacturing have matured significantly over the past decade as the demands of 300mm production made them mission critical. Still, there are several areas we believe will continue to evolve over the next three to five years.

Tool productivity will continue to be an area of significant change. Predictive maintenance and advanced process control are poised to become standard across all tools. Virtual metrology will evolve into a capability that will not only reduce the need for metrology tools and non-production wafers, but provide additional quality and throughput improvements.

Data collection rates will increase to >+100Hz with volumes increasing more than 100x. As larger amounts of data are able to be acquired, new methods will be needed for analyzing this data. Techniques which perform more automated analysis of data such as data mining and multivariate analysis will become more important in performing fast and efficient analysis of data. Tool suppliers will also leverage these techniques to embed intelligence into process tools, enabling more automated and "self-aware" tool operation. This increase in the volume of data will drive demand for a standard tool control platform to provide a common robust infrastructure.

A common platform will also allow the myriad of custom point solutions to be standardized into a manageable set of interoperable solutions that provide greater value. Just as we have seen consolidation of point solutions in enterprise resource planning (ERP) and manufacturing execution systems (MES), we expect to see similar consolidations in tool control.

Fab-wide throughput improvement and cycle time optimization trends will be mainly focused around implementing scheduling. Investment in this area is in its infancy in the semiconductor industry, but has a long history in other industries. The emergence of "giga-fabs" will drive a scale and complexity that will require these solutions to support incremental improvements in capital asset utilization. The initial investment in short-interval scheduling will transition into fab-wide and multi-fab scheduling initiatives. At the factory level, automated methods for scheduling will also move towards other areas that impact productivity. These include optimizing quality control sampling and maintenance management.

Even semiconductor test, assembly and packaging fabs are seeing the benefits of automation. Material dispatch decisions in these fabs are typically manual and vary with operator experience. This makes it difficult to manage hot lots and can result in poor on-time delivery. Recently, this segment has begun implementing automated rule-based dispatching to improve on-time delivery, reduce cycle time, and increase fab throughput.

AND WHAT ABOUT 200mm?

The need to increase productivity at 200mm is no different from what we see at 300mm. In particular, manufacturers with 200mm fabs want to increase output of constraint tools and increase fab throughput while maintaining cycle time. These needs are driving them to invest in automation solutions that have already been proven in 300mm fabs. Consequently, short-interval scheduling and tool control are now being implemented in many 200mm fabs.

AUTOMATION IS NOT JUST FOR SEMICONDUCTOR MANUFACTURING

Just as automation can help improve tool control in semiconductor fabs, sister industries such as MEMS, data storage device, and LCD display manufacturing are benefiting from automation solutions. MEMS and data storage device manufacturing have challenging feature sizes and shapes. The resulting process complexities require tight tool and process control. LCD display fabs are adopting tool-level automation for excursion control to improve yield. In each of these industries, scrap avoidance through better tool control is key to driving down cost.

THE FINAL WORD: AUTOMATION

The pressure on fabs to be better, faster, and cheaper continues. The latest rise in market demand and fab utilization has shifted the focus once again to increasing fab output. Automation will play an important role in helping fabs maximize output, as well as improve yields and process capability. ■

Authors: Scott Watson, Chris Keith. For more information please contact Scott Watson at Scott_Watson@amat.com