FabTime Cycle Time Management Newsletter

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Information

Mission: To discuss issues relating to proactive wafer fab cycle time management.

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Welcome

Welcome to Volume 4, Number 4 of the FabTime Cycle Time Management Newsletter. As I looked at the date on this issue, I realized that it's been exactly three years since we sent out the first issue of the newsletter. That issue was sent to 33 people. This issue goes out to 1271 people (a 3800% increase). Thanks to all of you for subscribing, and for passing along the newsletter to your colleagues!

In this issue, we are pleased to announce that Headway Technologies, our first customer, has upgraded to Version 4.5 of our software, and once again renewed their maintenance contract. We look forward to working with Headway during the coming year. We are also happy to announce the release of Version 5.0 of our cycle time management software, with many useful new features. Both press releases are included below.

Subscriber discussion topics for this month include material handling system metrics and cycle time reduction; the metric mean time to recover; and the cycle time effects of integrated metrology in the lithography area. This month's main article is about the cycle time effect of equipment downtime. When we ask people what they believe is the most significant contributor to cycle time in their fabs, the top response that we receive is "equipment downtime." In this article, we discuss the two primary mechanisms by which downtime drives up cycle time (through utilization and variability), and we propose three steps that fabs can take that may help to mitigate this effect. This is a topic on which we would particularly appreciate your responses, because we believe that it is a promising area for cycle time improvement for all types of fabs.

Thanks for reading!—Jennifer

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Community News/Announcements

Headway Technologies Upgrades to Version 4.5 of FabTime Software, Renews Maintenance Contract

Menlo Park, CA. March 26, 2003 - FabTime Inc. today announced that Headway Technologies has upgraded to Version 4.5 of FabTime's cycle time management software, and also renewed its maintenance contract for the next year. Headway, a recording head wafer manufacturer located in Milpitas, CA, was the first customer for FabTime's software.

Version 4.5 is a significant software upgrade for Headway. The new functionality includes advanced filtering, sorting, and data slicing capabilities, and an enhanced goal-setting interface. This version also implements results caching, which significantly increases chart speed.

"I particularly appreciate the speed improvements in the new version," said Ed Zawada, Headway's Director of Wafer Manufacturing. "This helps me, and the people who report to me, get to the data that we need quickly and efficiently."

"With every passing day, people here appreciate the advantages of FabTime more," said Bill Gardner, Headway's Senior Director of Manufacturing. "And we certainly appreciate FabTime's support in responding to our suggestions for the software."

"Headway's suggestions have helped us to continuously improve the functionality and usability of the software," said Jennifer Robinson, chief operating officer of FabTime. "We look forward to continuing to work with Headway during the coming year."

More information about FabTime's software is available at www.FabTime.com.

About Headway Technologies

Headway Technologies designs and manufactures recording heads for high performance hard disk drives. Headway is a part of the TDK group of companies (NYSE: TDK), the largest independent recording head supplier to the hard disk drive industry. Headway's wafer fabrication facility is located in Milpitas, California. The company's website is located at www.Headway.com.

FabTime Releases Version 5.0 of Wafer Fab Cycle Time Management Software

Menlo Park, CA. April 8th, 2003 - FabTime Inc. today announced the release of Version 5.0 of their cycle time management software for semiconductor wafer fabs. Version 5.0 includes:

- Enhanced tool state reporting, including the ability to trend and pareto tool state information by sub-state and/or reason code, and to trend downtime coefficient of variation.
- A new tool WIP and State list chart that shows a quick view of tool status (time in current Semi E10 state) and WIP in queue, to highlight tools that are idle, but have WIP waiting.
- Automatic generation of productive and standby tool-state transactions from WIP data, so that tool utilization can be calculated for fabs with minimal tool event logging.
- The ability to trend and pareto performance charts by line segment, e.g. pareto moves and WIP by line segment, or trend WIP turns for a particular segment of the process flow.
- Results caching, for improved chart generation speed.
- Enhanced international language support.

FabTime is designed to give wafer fab managers and their staff the information that they need, in real-time, to run their fabs effectively. FabTime extracts operational data from the fab manufacturing execution system (MES) every five minutes, and processes this data into a SQL Server data warehouse. Users can then access a comprehensive system of cycle time-related charts and alerts via a web browser from anywhere within the corporate Intranet. More information about FabTime's software is available at www.fabtime.com/software.htm.

FabTime welcomes the opportunity to publish community news and announcements. Simply send them to Jennifer.-Robinson@FabTime.com.

Subscriber Discussion Forum

Material Handling System (MHS) Metrics and Cycle Time Reduction

Jairo Montoya from STMicroelectronics wrote: "I noted that the focus on cycle-time reduction strategies is production-related, in most of the cases presented in your newsletter. Maybe the problem is not in decreasing processing times, but waiting times or transportation times. All the techniques you analyzed are very interesting and "pragmatic" (from an industrial point of view). However, what about working on transportation times? Can we be sure that the only possible reduction on cycle time must be done by acting on production equipment? Very often, "transportation" is considered as a non-value-added activity, but without it, no value is added... So, one of the most important problems in any production system is to manage transportation systems in such a way to optimize the global factory performance.

In semiconductor manufacturing, fab efficiency is governed by both throughput and cycle time. Under stationary conditions, there exists a relation between them, and optimizing average throughput has a positive effect on cycle time optimization, and vice-versa. In that context, how to measure the performance of a (automated) transportation system (AMHS)? When manual pod transport was used in wafer fabs, this problem was very difficult to analyze, and improvement efforts were focused on reducing processing times, scheduling rules, order release policies, and so on (all of them are "value-added" activities).

We think that, for a given set of scheduling and production conditions, wafer cycle time may be reduced by controlling the performance of the MHS. Thus, it is necessary to use specific metrics to evaluate its performance, such as manufacturing cycle efficiency (MCE=(total setup and running times)/(total setup, running, waiting and transport times)), or value added efficiency (VAE=total running time/(total setup, running, waiting and transport times)). Once the performance of the MHS is optimized, or at least well-controlled, the next step may be to act on the so-called "value-added" activities. In this phase, scheduling rules and order release policies have to be included in the analysis so as to get an actual optimized fab. When using a manual system, this task seems to be very difficult, and it is. However, with the advent of the 300mm wafer generation, automation is pivotal and data will be more available to evaluate those performances."

Mean Time to Recover (MTTRecover)

Chris Keith (Intel) wrote to ask for additional details regarding comments in Volume 4, Number 2 from an anonymous subscriber. That subscriber had written: "It was our conclusion that nearing full loading, the most important measurable parameter to control at the bottlenecks was the standard deviation of the MTTRecover (Recover meaning any event that stops the processing of production material when material is available: qual, test, PM, down, no op, etc.). "Managing" the variability of the MTTRecover at bottleneck tools has been the single most effective tool I have found for managing, predicting, and reducing cycle times in a fully loaded fab in my 18 years in the industry."

Chris asked for more details around this metric (MTTRecover) and its use. His questions, followed by the responses from the original subscriber, are included below.

1. Std Dev of MTTRecovery and its importance relative to reducing the mean, or average, of MTTRecover

--> Our fab is 100% Asyst SMIF/smart tag processing, including all standard monitors. Therefore, we know to the second when the tool is processing or not, and what it is processing. Additionally, the MES system will auto-log the tool for SPC out of control, abort, etc., most also will not process if PM is due (by wafer count, thickness, or time, etc.) Our MES system collects the proper data to be able to calculate standard deviation of any event sequence we want. Short cycle time is enables when MTBF is high, and standard deviation of MTTR is low. That means that the recovery time is predictable. Predictable MTTR allows proper scheduling of wip (standard, hot, and superhot lots) and PMs to be able to maximize the throughput of the tool. High MTTR is a signal of an unstable toolset which needs investigation to understand where is the problem: unplanned downtime, inconsistent PM times, defect notices, etc. which can be worked on to eliminate the variability of the toolset's performance.

2. Is this a real-time metric that is monitored regularly each day or shift or is it more of a general rule of thumb used to guide continuous improvement efforts and make decisions at the bottleneck, or both?

--> each day or shift is too short to get relevant statistics. Generally this is tracked/reported and impacted with other tool indices monthly. See above for additional comments related to this question.

3. Additional details around which events qualify as "recover" and need to be included in the calculation for std dev of MTTRecover? Does that include running engineering wafers? How about running smaller batches of material such as rework wafers or new products?

--> good question...any event that causes the stopping of salable product to be run through the tool (especially a bottleneck tool) must be managed. In our system engineering tests would be a "recover", but losing efficiency due to running an engineering split on production wafers or rework material (that would cause some kind of interrupt to the normal flow) wouldn't be directly noticed as a "recover" event, other than there would be a loss of efficiency on that tool for that day vs. its standard productivity.

Cycle Time Effects of Integrated Metrology in the Lithography Area

Hovav Gilan of Nova Measuring Instruments sent us a presentation that he delivered at the recent AEC/APC Conference (advanced equipment control / advanced process control) in Grenoble France. He used FabTime's Bottom Line Benefits calculator (available from http://www.fabtime.com/bottomline.shtml) to quantify the benefits that integrated metrology can give customers, coming up with an estimated $33M annual savings through a 10% cycle time reduction due to integrated metrology. The following factors were identified as contributors to this cycle time reduction:

- Metrology time is contained within Litho process time
- AMHS/Operator handling times are eliminated
- Queues before metrology are eliminated
- Cycle Time variability is reduced
- AMHS/Operators & Stockers are less busy and can better serve rest of Fab
- Gating capacity loss is eliminated (when Litho cell waits for results of send-ahead wafer)

You can request a PDF copy of this presentation from Jennifer.Robinson@FabTime.com.

Cycle Time Effects of Equipment Downtime

Introduction

For the past several months, we have been asking people about the issues in their fabs that contribute to cycle time problems. By far the most frequent response that we have received is "equipment downtime" (or "availability", or "bottleneck downtime", or "repair time variability" - all variations of equipment downtime). Therefore, we've decided to use this issue of the newsletter to discuss equipment downtime in more detail. Downtime contributes to cycle time in two primary ways: through driving up equipment utilization and through increasing variability. In this article, we briefly illustrate the two ways in which downtime drives up cycle time, and then we discuss proactive management of equipment downtime, to mitigate cycle time effects. We close with a request for your suggestions.

Example: Downtime and Utilization

Both scheduled and unscheduled downtime reduce the time available for production. This drives up equipment utilization by reducing standby time, where we use FabTime's definition:

utilization = productive time / (productive time + standby time).

Increasing utilization increases cycle time, sometimes dramatically. Cycle time is proportional to 1 / (1 - utilization). As utilization gets close to 100%, cycle time becomes very large. In a simple example, suppose that we have a tool that is busy processing WIP for 126 hours a week, on average, out of a total 168 hours. If this tool had no downtime, so that the remaining 42 hours a week are standby time, then the utilization would be equal to 126 / 168 = 75%. Using FabTime's operating curve generator (a free version is available from http://www.fabtime.com/charcurve.shtml), and assuming moderate variability in process times and times between arrivals, we estimate that the cycle time for this tool will be approximately 4X, or four times the theoretical processing time.

Now suppose that the same tool in fact has 16.8 hours a week of scheduled downtime (10%). If we still spend 126 hours a week processing, then the standby time remaining will be 42 - 16.8 = 25.2 hours, and the utilization will be equal to 126 / (126 + 25.2) = 83.33%. Even assuming minimal variability in this scheduled downtime (constant repair times, very short maintenance events), the operating curve generator still estimates that the average cycle time for this tool will be 6X, or six times the theoretical process time. In this example, then, a 10% scheduled downtime led to a 50% increase in cycle time (from 4X to 6X), due primarily to the decrease in standby time on the tool.

Standby time keeps down cycle times, by giving the equipment a chance to recover from variability in arrival and process times. Downtime, even scheduled downtime, cuts into this standby time, and drives up cycle time. In the long term, fabs include expected downtime in capacity planning models, and mitigate the effect of the downtime by adding extra capacity. In the short-term, daily or weekly downtime percentages can vary (e.g. the week that you do the annual PM on a tool), leading to cycle time spikes.

Example: Downtime and Variability

The other cycle time hit from downtime comes from variability. Downtime significantly increases variability in the fab. If we only had to deal with scheduled maintenance events, occurring at predictable intervals, the situation would be much more manageable. Instead, unscheduled downtime events occur randomly, and the recovery time can be highly variable. This variability makes cycle time worse, especially for one-of-a-kind tools.

Using our operating curve generator, we can look at the effect of two different measures of downtime variability. The first is coefficient of variation of repair time. Consider a simple example of a tool that is down 20% of the time, with a mean time between failures equal to 24 hours, an average process time equal to one hour, and coefficient of variation of process times and interarrival times both equal to 1.0 (moderate variability). Now let's vary the coefficient of variation of the repair time. We'll look at three levels, zero (constant repair times), 1, and 2. The resulting table shows the average cycle time X-factor predicted by the operating curve generator at 80% utilization.

CVRepair = 0	X-factor = 8.17
CVRepair = 1	X-factor = 10.09
CVRepair = 2	X-factor = 15.85

So, about a 25% increase in cycle time from constant to moderately variable repair time, and nearly a 100% increase from constant to more highly variable repair time. We believe that values from 1 to 2 are representative of what occurs in actual fabs, at least for unscheduled downtimes.

The other measure of downtime variability lies in the time between downtime events. Shorter, more frequent downtimes cause less of a cycle time impact than longer, less frequent downtimes, if the total time down is the same. Taking the middle scenario from above, with CV of the repair time equal to 1.0, let's this time vary the mean time between failures to look at three different cases: 8 hours, 24 hours, and 72 hours. What we're saying here is that the tool is down 20% of the time in all three cases. In the first case, it goes down on average every eight hours, for about 1.6 hours (1.6/8 = 20%). In the second case, it goes down once a day, for 4.8 hours, on average. In the third case, it goes down every three days, for 14.4 hours. This 14.4 hour repair time, in particular, allows WIP to build up, and increases cycle time. The resulting table shows the average cycle time X-factor predicted by the operating curve generator at 80% utilization:

MTBF = 8	X-factor = 7.53
MTBF = 24	X-factor = 10.09
MTBF = 72	X-factor = 17.7

So, about a 33% increase in cycle time when we go from having an average repair time of 1.6 hours to having an average repair time of 4.8 hours, than about a 75% additional increase as we go up to a 14.4 hour repair time.

Of course there are reasons to try to increase the time between equipment failures (for cost and yield reasons, for example, or because of setups). This example simply makes the point that longer downtime events have a more negative effect on cycle time than shorter downtimes, because of the WIP pile that can build up during the long downtimes. This effect is less pronounced for tool groups with more than one tool, but can still be observed.

Proactive Management of Equipment Downtime

The above examples illustrate, using numbers, what people who work in fabs already know from painful experience. Downtime increases cycle time. In this section, we'll discuss some possible mechanisms for mitigating the effect of downtime on cycle time. We think that the first step lies in obtaining sufficiently detailed, real-time information, so that managers can easily answer question such as:

- Which critical tools are spending too much time in unscheduled downtime?
- What failure codes are showing up for scheduled and unscheduled downtime events at critical tools?
- Which shifts are experiencing more unscheduled downtime? More scheduled downtime?
- Are our downtime improvement programs succeeding in reducing the coefficient of variation of repair times?
- Where do we see particularly long repair times? Do these tools have correspondingly high operation-level cycle times?

In our FabTime software, we've been adding more detailed downtime reports at the direct request of our customers, so that they can answer these questions. Specifically, we've focused on the downtime-related metrics that drive cycle time, such as the repair time coefficient of variation. Here are some of the downtime-related enhancements we've recently completed:

- The ability to trend and pareto tool repair time coefficient of variation for scheduled and unscheduled downtime for any specified grouping of individual tools (e.g. for a single tool, for all the tools in a tool group, for all the tools in an area, or for some other user-specified combination). Mean time between failures and mean time to repair are also reported.

- The ability to trend and pareto tool state information by failure code, e.g.

pareto time lost and number of occurrences of unscheduled downtime by failure code.

- The ability to trend and pareto tool E10 states and also sub-states (e.g. trending time lost due to a particular type of unscheduled downtime, or pareto scheduled downtime by type of PM performed).

- The ability to see a quick view of tool status (time in current E10 state) and WIP in queue for a list of tools, e.g. quickly identify WIP that is queued for qualified tools that are idle.

We believe that information of this type will enable more effective tool improvement projects, with particular focus on the utilization and variability-related aspects of downtime. And in turn, these projects will improve cycle times.

A second possible step in managing downtimes lies in scheduling maintenance events to minimize the likelihood of having large WIP bubbles build up during the maintenance. Naturally there are other factors that also drive maintenance schedules. But for cycle time, breaking up maintenance events at a tool and doing them separately, instead of grouping them all together for a longer downtime, can be beneficial.

A third step in mitigating the impact of equipment downtime lies in reducing the number of one-of-a-kind tools in the fab. Downtime variability is particularly detrimental to single path tools, and the fewer single path tools you have, the more robust your fab will be in recovering from equipment downtime. See Issue 3.3 for a more detailed discussion of the impact of single path tools on cycle time.

Summary

When we ask people what factors contribute to cycle time in their fabs, the number one response that we get is "downtime". Certainly equipment downtime is a fact of life in wafer fabs. What we've done in this article is review the reasons why downtime has such a significant influence on cycle time (utilization and variability). We've also proposed three steps for mitigating the effect of downtime on cycle time: increasing reporting of the downtime-related metrics that drive cycle time (such as repair time coefficient of variation), reviewing maintenance schedules to eliminate the longest periods of unavailability, and reducing single-path operations. We would be very interested to hear how you, our subscribers, reduce the impact of downtime on cycle times in your fabs.

Closing Questions for FabTime Subscribers

How do you mitigate the effect of downtime on cycle time in your fab? Do you think that downtime is the biggest contributor to cycle time in your fab, or is there some other issue that has a larger impact?

Further Reading

K.-T. Chang, O. Yu, H.W. Chang, Z. Su, and K.-s. Huang, "Automatic Commanding System for Periodic Shut Down & Recovery Plan - Using Real Time Dispatcher to Execute Annual Prevention Maintenance," Proceedings of the 2002 International Symposium on Semiconductor Manufacturing (ISSM2002), Tokyo, Japan, 2002. This paper deals with minimizing the negative effect of an entire fab being down for annual maintenance.

If you have a paper on managing equipment downtime in a wafer fab, we would be interested to hear about it, and would be happy to bring it to the attention of our other newsletter subscribers. Send abstracts, or papers, to Jennifer.Robinson@FabTime.com.

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TSMC (11)
TVS Motor Company (1)
UMC (6)
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