FabTime Cycle Time Management Newsletter

Volume 12, No. 4 July 2011

Information

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

Publisher: FabTime Inc. FabTime sells cycle time management software for wafer fab managers. New features in the software this month include SQL "where" filtering within object fields on charts and Lot Line Yield trend/pareto/list charts.

Editor: Jennifer Robinson

Contributors: James Morrison (KAIST); Guy Curry (Texas A&M University); Adar Kalir (Intel)

Table of Contents

Welcome

Welcome to Volume 12, Number 4 of the FabTime Cycle Time Management Newsletter! We hope that you're enjoying the season, wherever you are. We have a community announcement about two new FabTime employees in this issue. Our FabTime user tip of the month is about setting a default home page tab for login. In our subscriber discussion forum we have two responses to last month's article about queueing models for wafer fabs, as well as a new question about measuring coefficient of variation for effective process times.

Our main article this month is about PM scheduling. Equipment downtime in general is one of the top contributors to fab cycle time. Scheduled downtime, and more specifically preventive maintenance, contributes to fab variability, but is somewhat controllable. It's possible to take the cycle time impact into account when deciding whether or not to group maintenance events, and thus minimize the impact of the scheduled maintenance. In this article, we discuss ways to do that. We welcome your feedback.

Thanks for reading – Jennifer

FabTime

Tel: (408) 549-9932
Fax: (408) 549-9941
www.FabTime.com
Sales@FabTime.com

Community News/Announcements

FabTime Hires Two New Full-Time Employees

FabTime has grown from one software customer in 2000 (thank you, Headway Technologies!) to 25 customer sites today. To support our growing customer base, and ensure that we continue to offer world class customer support, FabTime is pleased to announce the hiring of **Michael Krist**, Senior Industrial Engineer, and **Sean O'Brien**, Director of Operations. Michael has a Master's degree in Industrial Engineering, and will be working on customer support, new installation projects and cycle time management training. Sean brings more than 20 years of experience with software development and technical management in both R&D and Customer Service. He'll be involved primarily with customer support management. He will be assigning engineering resources to work on both ongoing support issues and software enhancement requests.

We are delighted to welcome Sean and Michael to FabTime, and look forward to their help in supporting our growing family of software customers.

FabTime welcomes the opportunity to publish community announcements. Send them to newsletter@FabTime.com.

FabTime User Tip of the Month

Set a Default Home Page Tab for Login

FabTime's default behavior is to remember the last home page tab that you visited, and take you to that tab whenever you next login to FabTime (using the Login: Home option). However, FabTime now has an option (applied as part of Patch 100) to let you specify a default home page tab to visit upon login. To set the currently-displayed home page tab to always display as the first home-page tab upon login, simply click the link (in the left-hand pane, right below the link to change your email address) that says: "Login to this Tab".

This link acts as a simple toggle switch. Once you click it, FabTime will set the current tab to be the default login tab. The text on the link will then change to "Don't Login to this Tab". Clicking on the link again will reset FabTime to no longer use a default home page tab for login. In that case, FabTime will again display the most-recently visited home page tab the next time you log in.

You can easily change which tab is displayed on login. Even if a particular tab, say the Morning Meeting tab, is currently set as the default login tab, if you are looking at a different tab (say, the Photo tab), you can click on the "Login to this Tab" link. FabTime will then change the default login tab from your previous selection (Morning Meeting) to the current selection (Photo).

Please note that this option is only available for non-shared accounts.

If you have any questions about this feature (or any other software-related issues), just use the Feedback form in the software.

Subscriber Discussion Forum

Queuing Models for Wafer Fabs

Here are a couple of additional references to queueing models for wafer fabs (the subject of the main article in issue 12.03).

Professor **James Morrison** of KAIST sent us a reference to a paper that he worked on with **Don Martin** (retired from IBM).

J. R. Morrison and D. P. Martin, "Practical Extensions to Cycle Time Approximations for the G/G/m-Queue with Applications," *IEEE Transactions on Automation Science and Engineering*, Vol. 4, No. 4, 523-532, 2007. Available **here**.

Dr. Morrison adds: "It includes a discussion of "parallelism", which is useful for tools such as photolithography, and development of tool level queueing models at IBM."

We liked this **Note to Practitioners** from the article: "We develop extensions to intuitive closed-form approximations for the mean cycle time in queueing networks. Such approximations can be used to analyze the tradeoffs between equipment utilization and cycle time in a manufacturing facility. The extensions incorporate issues of practical import that have not been modeled in the literature and were motivated by the inability of existing models to accurately describe the performance of manufacturing in IBM's 200 mm semiconductor wafer fabricator. The utility of our extensions is that, using automated data collection systems, we are able to well model production tools and elucidate the sources of cycle time."

Professor **Guy Curry** of Texas A&M University sent us the reference to his textbook, an "introduction to queueing network models for manufacturing systems: mainly push systems, but with chapters on pull and Kanban":

Guy Curry and Richard Feldman, *Manufacturing Systems Modeling and Analysis (first and second editions),* Springer, ISBN 978-3-642-16617-4 (2nd edition 338 pages), 2010. Website: http://msma.tamu.edu/. This book is also available on Amazon.

Measuring Coefficient of Variation in Fabs

Adar Kalir from Intel wrote: "I would like to learn from others in the industry if anyone has attempted to develop an application that provides Coefficients of Variation for inter-arrival, effective process times, and inter-departure times by process step throughout the process flow, to highlight root causes for cycle time in a scientific manner."

FabTime Response: We do report Coefficient of Variation (CV) for interarrival times in FabTime's software (by tool, toolgroup, operation, etc.). We have chosen not to implement CVs for effective process times because the calculation for that are quite complex, and require a number of assumptions. As an example, if a lot is in front of the queue, and the tool goes down, that downtime is part of the effective process time of the lot. But if another lot arrives and goes to a place in the queue ahead of that lot, then the remaining downtime must be attributed to that second lot. This has not been a priority for our customers to date. We would certainly be interested to know if anyone else is routinely measuring and reporting CVs for effective process times and/or departure processes.

FabTime welcomes the opportunity to publish subscriber discussion questions and responses. Simply send your contributions to Jennifer.Robinson@FabTime.com.

PM Scheduling and Cycle Time

Introduction

A newsletter subscriber asked us recently if we had any references on the impact of preventive maintenance (PM) scheduling on cycle time. We were surprised to realize that, although we talk about this extensively in our one-day cycle time management class, and have mentioned it briefly in past newsletters, we've never dedicated a full article to this topic. In this article, we remedy that oversight.

Background

Equipment downtime is considered by many people to be the largest contributor to wafer fab cycle time. We have been surveying people about cycle time contributors for close to ten years now, and downtime has consistently been rated the top issue. As we discussed in Issues 4.04 and 5.07, downtime increases fab cycle time through its effect on both tool utilization (by reducing available standby time) and variability.

Equipment downtime events are normally classified as unscheduled or scheduled. The SEMI E10 standard for definition and measurement of equipment reliability, availability, and maintainability (RAM) is an industry guideline for classifying downtime events. Under E10, preventive maintenance and associated activities are classified as scheduled downtime (along with other planned events like setups, facilities downtime, etc), while unplanned downtime events (AKA random failures) are classified as unscheduled downtime.

While unplanned downtime events often cause more serious cycle time problems than planned downtime events, scheduled events are also significant. Preventive maintenance is something that affects fab cycle time every day, but it's also a relatively controllable effect. The mere fact that we're talking about scheduled downtime means that we have in our power to schedule the events to minimize their effect on cycle time. It's been our experience, however, that this doesn't always happen, in part because of a traditional emphasis on increasing the mean time between failure events.

Shorter, More Frequent vs. Longer, Less Frequent Events

Historically, one of the key metrics for tracking equipment performance in fabs has been mean time between failures. The longer a tool stays up without failing, the better. This is generally a good thing when one is looking at unscheduled downtime events, where the time that the tool is down is relatively independent of the length of time that it was up before going down. The longer the tool is up, in this case, generally correlates with a smaller overall percentage of time spent down. This makes mean time between unscheduled downtime events a useful metric.

However, the mean time between scheduled downtime events, though often reported, is not particularly useful as a metric, and can in fact be counterproductive. The reason for this is that with preventive maintenance, the total amount of time that the tool is required to be offline is usually relatively fixed. There is a certain amount of maintenance that needs to be done on the tool per year, and the question is how to schedule that maintenance. You can have longer, less frequent events, or shorter, more frequent events, for the same total amount of unavailable time.

And while longer, less frequent events result in a higher mean time between downtime events, longer, less frequent downtime events are much worse for cycle time than shorter, more frequent downtime events. This is because long downtimes (whether scheduled or

unscheduled) contribute greatly to variability and cycle time, particularly for single path tools.

When a tool is unavailable for an extended period of time, WIP piles up in front of that tool. When the tool comes back online, it can take quite a long time to work off the pile of WIP, with consequently long per-visit cycle times. Even when you have multiple tools in a tool group, having one of those tools unavailable for an extended period causes the other tools to be run at a higher utilization, and still leads to cycle time problems.

PM Scheduling

PM schedules are, to some extent, a controllable knob (more so than unplanned downtime events, certainly). You can't just decide to do all of the year's maintenance at one time, because you run the risk of unplanned failures occurring if you don't keep up with maintenance schedules. So that (hopefully) doesn't happen very often. But it can still be tempting to group smaller maintenance tasks, or to take care of some scheduled downtime when a tool is already down for unscheduled downtime. This reduces the number of times that the tool is reported offline over a given time period, and can reduce tool qualification time (time spent preparing the tool to once again run wafers, after a downtime event).

However, as discussed above, grouping scheduled maintenance items together, or grouping them together with other downtime events, is terrible for cycle time. What you want, from a cycle time perspective, is to always have the time period that the tool is unavailable be as short as possible. Then you want to bring the tool back up, work off the pile of WIP that has accumulated, and only then take the tool down again to take care of the next planned event.

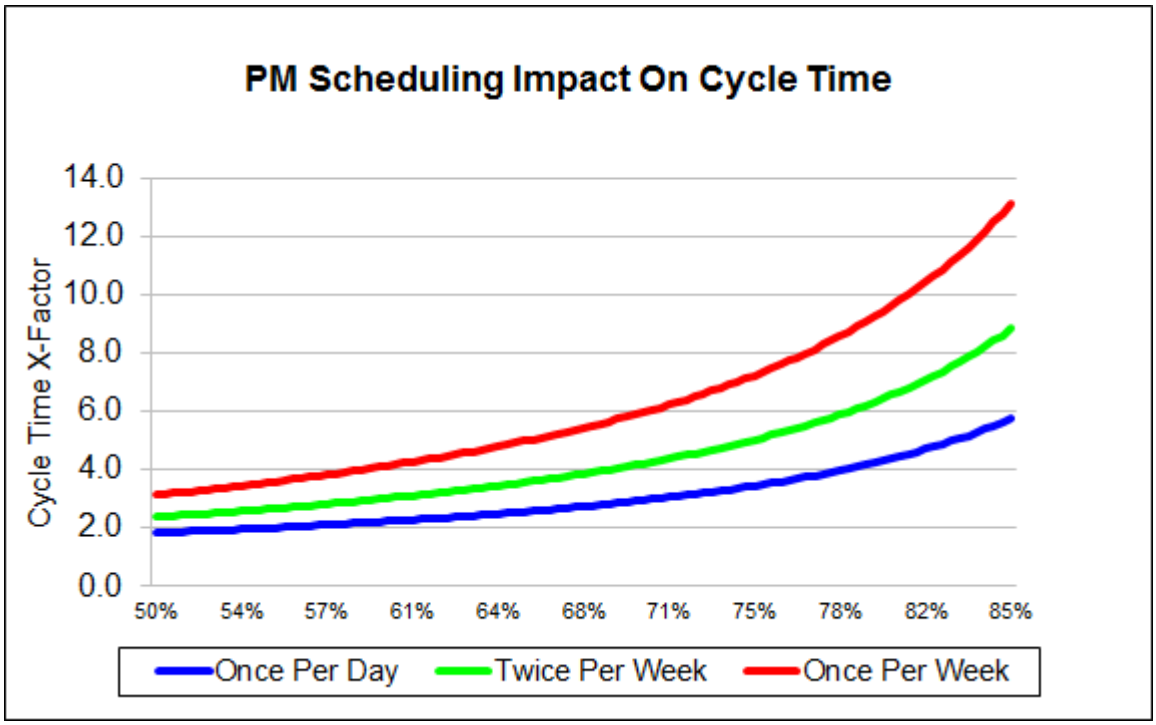
Obviously, there are limits to this. If re-qualifying the tool takes 2 hours, and you have two separate 10 minute maintenance tasks, by all means group them together. But if you're looking at a four hour task and an eight hour task, you're probably better off bringing the tool back up in between, especially for a one-of-a-kind tool. Assessing the question of exactly where to draw this line is a good use of small simulation models, or even queueing models. It's quite easy to find examples where even if the total amount of time that the tool is unavailable is a bit larger (due to quals), breaking up the unavailable time still results in a lower overall cycle time through the tool.

Example

Suppose we have a one of a kind tool that is 85% utilized, has moderate variability (arrival coefficient of variation = 1.0, process time CV = .5), and requires 16.8 hours of PM time per week (10% of total time). If we do the maintenance all at once, in one 16.8 hour chunk each week, the average cycle time for lots passing through the tool will be approximately 13.1X (according to FabTime's queueing-based operating curve generator, discussed in Issue 12.03, illustrated at the top of the next page).

If we break up the PM time into two 8.4 hour chunks, then the average cycle time for lots going through the tool will drop to 8.8X. And if we break the PM time into 7 chunks (one per day), then the average cycle time per visit drops to 5.8X. That's a greater than 50% reduction when we go from a weekly PM to a daily PM.

Of course this is an upper bound on the effect. Breaking up the maintenance may require additional qualification time, driving up the cycle time for the shorter/more frequent maintenance configurations. However, again looking at the operating curve generator, we can look across to see that we could increase the



utilization of the system with daily PMs up to about 93% utilization, before the cycle time would match the system with the weekly PM. Or, conversely, we would have to lower the utilization of the system with the weekly PM down to about 69% to match the 5.8X cycle time of the system with daily PMs. That is, breaking up the maintenance reduces the cycle time by so much that we can afford a bit of extra re-qualification time, if needed, in this particular example.

A Few Final Points on PM Tracking and Scheduling

■ If mean time between events isn't a good thing to track for scheduled downtime, what should you track? Let's think about our goals. We want the average duration of the maintenance events to be as short as possible, the CV of the maintenance time to be as short as possible, and the total percent of time spent down to be as small as possible. The mean time between scheduled downtime events isn't important, and can be detrimental, if you, for example, keep a tool up instead of doing an important PM.

■ Although we're recommending breaking up maintenance events into smaller chunks, instead of grouping them, it's still true that if you have a fab shutdown, or an extended period when you're not expecting any WIP to a tool, then you should by all means go ahead and get whatever maintenance you can out of the way.

■ Just as it doesn't make sense to take one tool down for longer than necessary at one time, it also doesn't make sense to take more than one tool in the same tool group down at the same time, if you have a choice. Staggering maintenance events is much better than doing them simultaneously, so that some amount of WIP continues to get through the tool group. This, we believe, is already common practice in fabs, so we haven't felt the need to spend much time talking about it here.

Conclusions

There are many sources of variability in wafer fabs, including preventive maintenance events. PM schedules, however, are a relatively controllable knob.

Scheduling PMs well can reduce variability in the fab, and thus reduce overall cycle times.

While it can be tempting to group smaller maintenance activities together, or to group them in with other downtime events, this is generally counterproductive for cycle time. What's best for cycle time is to have each period of unavailable time be as short as possible, particularly for one-of-a-kind tools, to keep lots moving through the tool smoothly. For cycle time, then, it's better to break PM activity into the smallest possible chunks, and make the tool available for production in between.

Clearly, there are limits to this approach, depending on the qualification time required to bring a tool back up, staffing issues, etc. However, it may be worth taking a look at your PM schedules, to see where you may be introducing more variability into the fab than needed. Tracking average and maximum time offline for scheduled downtime, rather than tracking the time between events, is a very good place to start.

Closing Questions for FabTime Subscribers

Does your maintenance team try to group preventive maintenance events, or break them up into the smallest possible chunks? Or something in between? Do you measure mean time between downtime events for scheduled downtime, or only for unscheduled downtime?

Further Reading

- The SEMI E10-0699 standard for definition and measurement of equipment reliability, availability, and maintainability (RAM), SEMI, 2008.
- J. Robinson and F. Chance, "Cycle Time Effects of Equipment Downtime," *FabTime Newsletter*, Vol. 4, No. 4, 2003.
- J. Robinson and F. Chance, "Quantifying the Effect of Tool Downtime," *FabTime Newsletter*, Vol. 5, No. 7, 2004.
- J. Robinson and F. Chance, "Queueing Models for Wafer Fabs," *FabTime Newsletter*, Vol. 12, No. 3, 2011.

Subscriber List

Total number of subscribers: 2689, from 437 companies and universities.

Top 20 subscribing companies:

- Maxim Integrated Products, Inc. (155)
- Intel Corporation (146)
- Micron Technology, Inc. (103)
- Western Digital Corporation (70)
- Carsem M Sdn Bhd (68)
- Texas Instruments (65)
- X-FAB Inc. (65)
- International Rectifier (62)
- TECH Semiconductor Singapore (61)
- ON Semiconductor (59)
- STMicroelectronics (57)
- Analog Devices (52)
- GLOBALFOUNDRIES (52)
- Freescale Semiconductor (51)
- IBM (50)
- Telefunken Semiconductors (47)
- Skyworks Solutions, Inc. (45)
- Infineon Technologies (43)
- Cypress Semiconductor (35)
- Seagate Technology (35)

Top 4 subscribing universities:

- Ecole des Mines de Saint-Etienne (EMSE) (12)
- Arizona State University (8)
- Ben Gurion Univ. of the Negev (8)
- Nanyang Technological University (8)

Sampler Set of Other Subscribing Companies and Universities:

- Abbie Gregg Inc. (3)
- Applied Materials Corporation (17)
- Boise State University (1)
- California Polytechnic State Univ. (2)
- Central Graphics (1)
- E2V Technologies (3)
- FormFactor (2)
- International SEMATECH (11)
- Intersil (10)
- KGP (1)
- Korea Information Society Development Institute (1)
- Macquarie Electronics (1)
- Micrel Semiconductor (6)
- NXP Semiconductors (26)
- ORT Montenegro Advocacy Prog. (1)
- Shanghai Jiatong University (1)
- Solyndra (1)
- Tru-Si Technologies (1)
- Viasys (1)
- Virginia Tech (7)

Note: Inclusion in the subscriber profile for this newsletter indicates an interest, on the part of individual subscribers, in cycle time management. It does not imply any endorsement of FabTime or its products by any individual or his or her company.

There is no charge to subscribe and receive the current issue of the newsletter each month. Past issues of the newsletter are currently only available to customers of FabTime's web-based digital dashboard software or cycle time management course.

To subscribe to the newsletter, send email to newsletter@FabTime.com, or use the form at www.FabTime.com/newsletter.htm. To unsubscribe, send email to newsletter@FabTime.com with "Unsubscribe" in the subject. FabTime will not, under any circumstances, give your email address or other contact information to anyone outside of FabTime without your permission.

FabTime® Software for Assembly and Test

"Instead of spending time preparing reports, shift facilitators can get the data they need quickly from FabTime, and then spend their time making real improvements."
Mike Hillis
Cycle Time and Line Yield Improvement Manager
Spansion Fab 25

FabTime Subscription

One low monthly price includes
- Software installation and real-time connect to your MES
- End user and system administrator training
- Unlimited users via your Intranet.
- Software maintenance and regular upgrades (approx. 4 per year, via our no-downtime patch system)
- Add-on dispatching and planning module for a slightly higher monthly fee

Interested?

Contact FabTime for technical details and/or a web-based demonstration.

FabTime Inc.
Phone: +1 (408) 549-9932
Fax: +1 (408) 549-9941
Email: Sales@FabTime.com
Web: www.FabTime.com

FabTime's Web-Based Dashboard is Fully Applicable for Assembly & Test Facilities

- Do your customers (internal or external) want more visibility into your factory?
- Is it difficult to look at trends in equipment performance, or tie equipment performance to throughput and cycle time?
- Does your factory lack real-time reporting?

FabTime can help. FabTime saves your management team time daily by turning MES data into information, via a real-time web-based dashboard that includes lot dispatching. FabTime saves your IT staff time by breaking the cycle of custom-developed reports. Most importantly, FabTime can help your company to increase revenue by reducing cycle times up to 20% for regular lots, and even more for high-priority lots.

Although FabTime was originally designed for front-end manufacturing, you can use FabTime for your assembly or test facility. You simply need to have a transaction-based manufacturing execution system. FabTime can link to all commercial systems commonly used in the industry (e.g. WorkStream, Promis, Eyelit, Mesa, FactoryWorks) or can link to internally developed systems. FabTime can pull data from multiple databases if needed (e.g. WIP transactions from the MES, tool transactions from another system). FabTime is currently being implemented in two assembly and test facilities, with no major technical hurdles.

FabTime Applicability for Back-End Factories

- FabTime handles lot merging and splitting, with full tracking of overall cycle times.
- All chart quantities (moves, WIP, etc.) can be displayed as die, with data tables formatted for readability of large quantity values.
- Custom assembly and test parameters (applicable to WIP or tool state transactions) can be mapped.
- Specific reports for wire bond area are in process (die and component placements, etc.).
- Custom dispatch factors allow for incorporation of back-end-specific data used in dispatch decisions (e.g. availability of boards, and minimization of sequence-dependent setups).