FabTime Cycle Time Management Newsletter

Volume 18, No. 2 April 2017

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 version just released by FabTime include the ability to sort stacked charts by total, the ability to place a new series on the right-hand Y-axis when editing charts, and a new E10 age filter.

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Keywords: Variability; Shutdown; Tool Availability

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Welcome

Welcome to Volume 18, Number 2 of the FabTime Cycle Time Management Newsletter! We have no community announcements this month. Our FabTime software tip of the month is about toggling the display of data values on bar chart series. Though we have no new subscriber discussion, we have used that section of the newsletter to share two recent papers that we think will be of particular interest to our subscribers. The first is about sources of variability in wafer fabs. The second is about breaking up long PMs to improve cycle time.

Our main article this month is about temporary fab shutdowns. We discuss the reasons and general types of temporary shutdowns, the ways that people prepare for planned shutdowns, and recovery from shutdowns. We also discuss the impact of fab shutdowns on factory systems, particularly reporting systems. We would appreciate any feedback from newsletter subscribers who have real-world experience in managing shutdowns from the fab side.

Thanks for reading – Jennifer

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Community News/Announcements

FabTime welcomes the opportunity to publish community announcements, including conference notices and calls for papers. Send them to newsletter@FabTime.com. We have no announcements at this time.

FabTime User Tip of the Month

Toggle Data Values on Bar Chart Series

New in Patch 108 (recently released by FabTime) is the ability, for Javascript charts, to display data values on or above the bars for any bar chart. To cycle through the available options, simply click repeatedly on the "#" symbol located in the lower left-hand corner of the chart (just above the "L" that is used to toggle legend display).

The options are:

- No data values displayed. Values will be included in the data table to the right of or below the chart, and will be visible as a tool-tip when mousing over a bar, but will not otherwise be displayed on the chart.
- Display values within bars. When looking at a stacked bar chart, values will display for each segment of the bar. However, for charts with an extensive number of stacked categories, the data values may become illegible. An example of a stacked bar chart showing within-bar data values is shown at the top of the next page. Note that the values are not quite legible in the left-most stacked bar, because the bar is so small.
- Display values at the top of bars. For stacked bar charts, FabTime will only display the total value at the top of the stack.

The data value setting is saved with the chart definition when you a chart to a home page tab. You can change this setting temporarily from the home page tab for any single chart by clicking on the "#" symbol.

This feature requires Patch 108 to be installed, and also requires that the "Active" setting for the chart is "Javascript".

If you have questions about this item, or any other FabTime software questions, just use the Feedback form inside FabTime's software. Subscribe to the separate Tip of the Month email list (with additional discussion for customers only). Thanks!

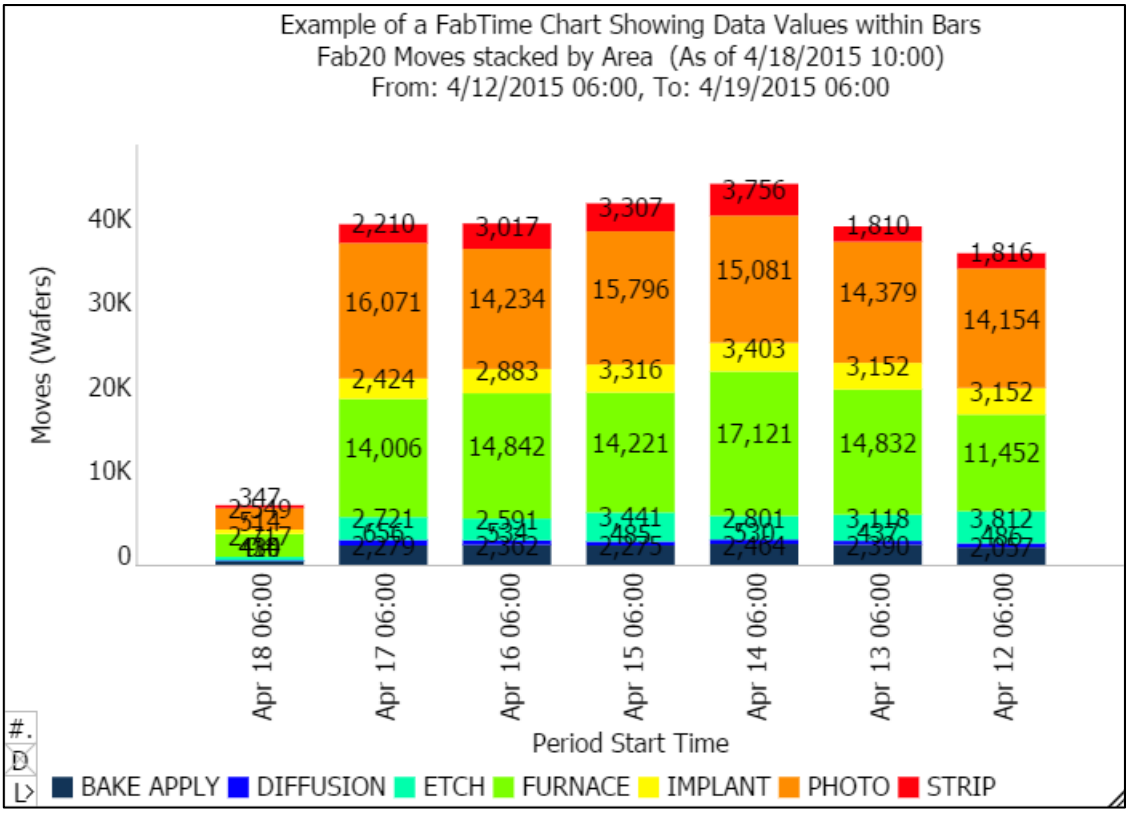

Figure 1. Example of Stacked Bar Chart Showing within Bar Data Values

Subscriber Discussion Forum

We have no new subscriber discussion questions this month. We would, however, like to take this opportunity to bring to your attention two papers from the December 2016 Winter Simulation Conference that we feel are of particular interest to FabTime newsletter subscribers.

Sources of Variability in Wafer Fabs

Kean Dequeant and Philippe Vialletelle (STMicroelectronics) and Pierre Lemaire and Marie-Laure Espinouse (Univ. Grenoble Alpes), "A Literature Review on Variability in Semiconductor Manufacturing: The Next Forward Leap to Industry 4.0," *Proceedings of the 2016 Winter Simulation Conference*, 2016. Available for PDF download from the conference website.

This paper undertakes what the authors believe (and we cannot dispute) is the first literature review concerning sources of variability in semiconductor manufacturing. They discuss the need for a better understanding of variability in wafer fabs, as high mix low volume manufacturing is increasing. They review the general characteristics of semiconductor manufacturing that result in broad categories of variability and the impact of that variability on cycle time. Their operating-curve-based methodology is quite consistent with FabTime's (and in fact, a paper that Jennifer co-authored on

capacity loss factors in wafer fabs is referenced).

The authors provide a very nice table that identifies some 25 sources of variability in fabs, with a tabulation of articles that discussed each, and a classification of each into a broader category: equipment specific; product induced; operational; or structural. These are discussed in more detail to provide an idea of their relative impact on fab variability.

Where possible, the authors perform simulations to assess this impact. However, they note that "identifying the sources of variability may not be enough: The root causes of the specific behaviors responsible for extra queuing times need to be understood in order to be sure that the statistics used to successfully model the sources incorporate these aspects. Therefore, in order to create valid simulation models, and in turn create dynamic cycle time models that fit the "to be" reality, it is essential to centralize the knowledge of experienced people working on the considered toolsets." They conclude with a "call for more focus on the fundamental understanding of the manufacturing systems and a greater use of industrial data in research in order to find today the solutions for the "smart industries" of tomorrow."

For anyone seeking to understand the sources of variability in a fab, this paper offers a good starting point. There's also a comprehensive set of references to seek further information.

Splitting PMs to Improve Cycle Time

Kosta Rozen and Néill M. Byrne, "Using Simulation to Improve Semiconductor Factory Cycle Time by Segregation of Preventive Maintenance Activities," *Proceedings of the 2016 Winter Simulation Conference*, 2016. Available for PDF download from the conference website.

We have been talking for years in this newsletter (see Issue 12.04, for example) and in our cycle time management course about how one method of improving wafer fab cycle time involves breaking up long maintenance events (due to their impact on variability). Therefore, we were delighted to see this article, in which the authors not only recommend breaking up long maintenance events, but identify the best situations in which to do so. They do consider the fact that breaking up (or segregating) a PM will require additional setup time. They then look at the fab-wide impact of splitting PMs on overall fab cycle time, via simulation.

They find that "there are only certain types of candidate tools that will improve factory velocity by segregating PMs. Most notably, non-constraint toolsets with many operations, few machines, long PMs and where possible short PMSUs (post-PM setups) are the best candidates for selection."

FabTime has primarily looked at the PM splitting decision at the toolset level, rather than at the fab level. We've also used primarily queueing models, rather than simulation models, to explore this effect. We are pleased to see that the authors find significant improvement at the fab level (in some cases) due to reduction in departure variability from the affected tools. While the queueing models certainly predict the highest impact for toolsets with few tools, short setup times, and long PMs, it takes a full-fab model to explore the impact of number of operations passing through each toolset. We thus found that result particularly interesting.

We recommend that newsletter readers take the time to download and read this paper in full. It is a practical application of simulation that offers a concrete method of improving wafer fab cycle time through changes in PMs.

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

Variability Impact of Temporary Fab Shutdowns

By Mike Hillis, Frank Chance and Jennifer Robinson

In reading the above-mentioned "Literature Review on Variability in Semiconductor Manufacturing", it struck us that we have never written in the newsletter about temporary fab shutdowns. Shutdowns are a factor that clearly affects both capacity and variability (not to mention yields) in wafer fabs and we think that they warrant further discussion. As those of you who work in fabs have much more experience than we do with managing temporary shutdowns on the floor, we would appreciate any subscriber feedback to this article.

Background on Temporary Fab Shutdowns

There are a number of reasons why temporary fab shutdowns occur. Broadly speaking, they are a) planned due to required facilities activities; b) planned to provide vacation time; and c) unplanned. Here a) and b) can overlap, as when a required facilities shutdown is timed to occur over a holiday period. During an industry downturn, a vacation shutdown might also be used as a method of cost-cutting. But basically, there are planned and unplanned shutdowns. Methods of managing these shutdowns vary depending on the duration of the shutdown.

A planned facilities shutdown occurs because there are systems that can't be interfered with while the fab is in production that need to be maintained. Sometimes these maintenance activities are preventive in nature while at other times a repair of some known issue is needed. A brief planned vacation shutdown might occur when a fab chooses to give employees time off for Thanksgiving or July 4th, even when no major facilities issues need to be addressed.

The primary cause of an unplanned shutdown is a power failure or other natural disaster. We can easily find stories in the news about fabs that were shut down after the earthquake in Japan in 2011 or in Silicon Valley during rolling blackouts back in 2001. We even ran across a story about a squirrel taking down a TI fab in 2001. We've heard anecdotally about snakes and frogs, but there's no need to dwell on that here.

For the most part, such unplanned shutdowns are outside a fab's control, but we would imagine that such things as backup power systems have improved over the years. We have heard of fabs monitoring electrical storms and occasionally holding back from starting large batch runs in case of a power loss.

Preparing for Planned Shutdowns

Preparing for a planned shutdown, unless it is going to be a very short vacation shutdown, is an extensive process that can take several weeks. The two main categories of planning that drive fab variability are deciding what equipment maintenance will take place immediately before or during the shutdown, and managing WIP placement prior to the shutdown.

Equipment Maintenance: Some fabs perform longer preventive maintenance (PM) tasks during shutdowns. Others prefer to perform this maintenance right before the shutdown, to minimize the number of people in the fab during the shutdown.

One important point here for variability reduction is to avoid scheduling too many tools for PM at the time of the shutdown. The reason for this is that PMs for many tools are on a recurring calendar schedule (30 days, 60 days, etc.). If too many of these are done at shutdown time, they will all come due for the next PM at around the same time, when there is no shutdown planned. This can lead to recurring waves

of equipment unavailability throughout the rest of the year.

WIP Management: In order to minimize yield loss, fabs hold WIP at designated "safe" spots prior to any planned shutdown that is expected to last more than a day or so. Because there can be multiple operations between safe spots, a safety window is required for each, during which time lots are held prior to the shutdown. For example, the safety window prior to a long batch process would probably be longer than other safety windows. The safety window would also be longer prior to any time constrained processing regions. In general, designation of safe spots and safety windows is a complex, technology-dependent process. Once programmed, factory systems can help with this by placing all lots on hold at the safe spots at the appropriate time. (See Chang et. al., referenced below, for an automated methodology for this.)

Recovering from Shutdowns

It can take weeks to recover from a major unplanned shutdown, especially if there is a significant power loss. Generally the diffusion furnaces (with large loads), and sometimes the steppers, have the toughest recoveries. Scrap across the fab will almost certainly be significant.

Recovering from planned shutdowns is, of course, much easier. However, it can still take a fair bit of time. This is because grouping lots together at safe spots introduces considerable variability when the fab is brought back online. This is particularly true if the safe spots tend to be constraint operations. Fabs need to analyze which are the best safe spots both in terms of minimizing yield problems and in terms of distributing the WIP to reduce WIP bubbles. It can take several days to smooth the WIP back out in a fab after a planned shutdown. There will also likely be extra tool qualifications required after the shutdown, and perhaps extra scrub and inspection operations. These requirements reduce capacity, and hence increase cycle time.

Shutdown and Factory Systems

Shutdowns need to be incorporated into a fab's order commitment system. It is not usually enough to simply add the length of the shutdown to the planned cycle time of each lot in process. Even for a short shutdown, the impact on overall cycle time will likely be larger than that. For instance, even a 24-hour shutdown that doesn't require safe points will have some slowed productivity going into the shutdown, and extra tool qualifications after the shutdown. More significant shutdowns, where lots are held at safe points, might add a week of cycle time due to increased variability, in addition to the duration of the shutdown. This adjustment to the order commitment system should take place as early as possible, to avoid surprising customers.

The issue with shutdowns that FabTime has wrestled with concerns their impact on fab management reports. With every metric there is the question of how to handle the shutdown. For example, OEE and cycle time – should shutdown time count against OEE and cycle time, or not? If the fab is shut down for a week and cycle times go up by two weeks as a result, the planned cycle time given to customers should reflect that additional cycle time. This is clear.

However, in terms of factory performance assessment, we shouldn't hold the additional cycle time directly attributable to the shutdown against the fab's management team, or anyone whose performance is evaluated according to fab cycle time. We might, however, want to incentivize the fab management staff to reduce the post-shutdown recovery time via WIP smoothing methods.

For every metric there are at least two, if not more, ways of handling the shutdown. Depending on the end-customer for the

report, the answer may be "we need to see it 2 (or 3) different ways."

Over the years we have developed several different ways of dealing with shutdowns in FabTime's software, and this is still an area of active development. One way that we handle shutdowns is to put all WIP and tools into a known shutdown state in FabTime at the start of the shutdown, and then bring them out of this state at startup. This known shutdown state can then be easily excluded from cycle time reports where necessary. The shutdown state on tools is typically non-scheduled time, so it can be disregarded on most tool reports. However, unless this system of assigning states is automated, it is prone to breakage. For example, a shutdown may occur for which no one remembers to run the shutdown script (or the startup script). Even when the system is automated it can fail if the schedule table it is reading from is not updated with the shutdown information.

[One point that FabTime would like to make here to our customers is that the earlier we know ahead of time about a planned shutdown, the more able we are to help via such methods, and the less likely we are to be calling you to ask why we have stopped receiving new data into the system.]

Conclusions

Fab shutdowns are a known (if apparently little researched) source of variability in wafer fabs. How much of an impact shutdowns have varies by fab. Some fabs find regular facilities-driven shutdowns necessary to keep fab support systems running smoothly, while others seem to manage with minimal shutdown. Some fabs shut down over holiday periods to reduce costs. Others choose not to take that hit to capacity and cycle time. And, of course, any fab can be subject to unplanned shutdowns due to power issues or natural disasters.

Planned shutdowns of more than a day or two require a considerable amount of work ahead of time, to make sure that lots are stopped in a manner that minimizes yield loss. This stopping of lots at safe points introduces variability into the fab, as lots are bunched together at a subset of operations. Recovery from a shutdown thus takes time, too. It is up to each fab to weigh whether the benefits of the shutdown outweigh the costs in terms of lost capacity and increased cycle time.

Questions for FabTime Newsletter Subscribers

Are there other reasons that we've missed for planning a temporary fab shutdown? Does your fab have an automatic system for determining when lots should be stopped at each safe point, or is this a somewhat manual process? Are there other impacts of shutdowns on fab variability that we've missed here? If you have an older fab and do not schedule shutdowns, how do you manage issues related to your aging infrastructure?

Further Reading

J. Beck, "Managing a Successful Temporary Plant Shutdown and Return to Service," AreaDevelopment.com, 2013. [This is a general article, not specific to wafer fabs.]

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.

K. Dequeant and P. Vialletelle (STMicroelectronics) and P. Lemaire and M.-L. Espinouse (Univ. Grenoble Alpes), "A Literature Review on Variability in Semiconductor Manufacturing: The Next Forward Leap to Industry 4.0," *Proceedings of the 2016 Winter Simulation Conference*, 2016.

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