FabTime Cycle Time Management Newsletter

Volume 13, No. 3 June 2012

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 the ability to specify FromTime (hh:mm) and ToTime (hh:mm) for checking each alert, and improved stability of Excel export for data tables.

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Contributors: Michael Hair (L-3 Communications); Bob Kotcher (Simitar); Steven Brown (IBM)

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Welcome

Welcome to Volume 13, Number 3 of the FabTime Cycle Time Management Newsletter! We have been keeping busy at FabTime these days with installations for sites 27-29. We've also just released a preview version of our latest core patch, with a variety of upgrades, and are awaiting customer feedback.

In this issue of the newsletter, we have an announcement about a new member of the Fab Owners Association. Our FabTime tip of the month is about understanding how actual and planned XFactor values are used in FabTime. We have two subscriber discussion submissions: a follow-on to the main article in the last issue about choosing the appropriate level of capacity planning; and a new question about downtime reason codes.

In our main article this month, we take a look at the reasons that reentrant flow makes managing cycle time and WIP in wafer fabs challenging. We first focus on the fundamentals - the ways that multiple visits to the same tool affect utilization, number of tools, and variability. We then explore some of the ways that reentrant flow affects capacity planning and dispatching. We welcome your feedback.

Thanks for reading – Jennifer

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Community News/Announcements

Fab Owners Association Welcomes New Device Manufacturer: Polar Semiconductor

As announced by the FOA on May 31st, Polar Semiconductor is their newest member device manufacturer. This is from the announcement: "Located in Bloomington, Minnesota, Polar Semiconductor is a wholly owned subsidiary of Sanken Electric Company, Ltd. We operate a 200,000 square-foot facility that includes 62,000 square feet of cleanroom space for wafer fabrication. Our manufacturing facilities consist of a six-inch (150mm) and an eight-inch (200mm) wafer fab, which gives us the ability to process more than 4,000 wafers a week. We also have the capability to expand our fab to accommodate future customer and industry growth."

The next FOA meeting will take place at Semicon West in San Francisco on July 12th. More details are available at http://www.waferfabs.org. FabTime is an associate member of the FOA.

FabTime welcomes the opportunity to publish community announcements, including conference notices and calls for papers. Send them to newsletter@FabTime.com.

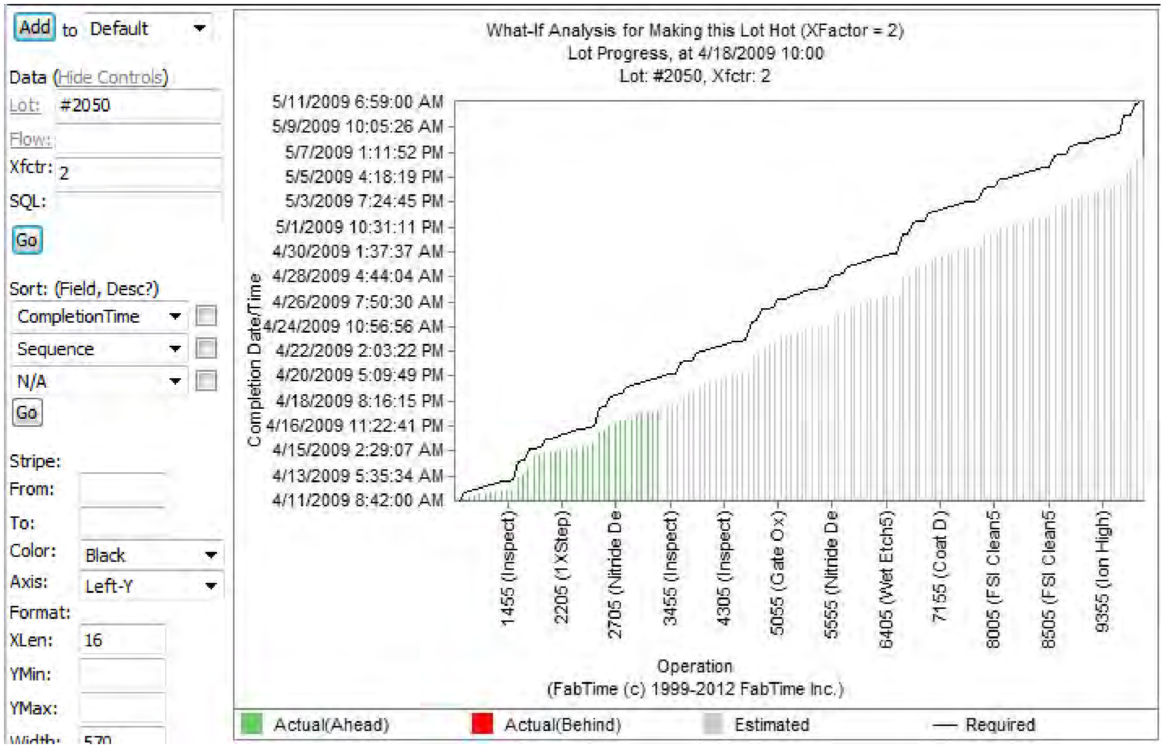
FabTime User Tip of the Month

Understanding Actual and Planned XFactor in FabTime

XFactor is the ratio of total cycle time to theoretical cycle time. It measures how you are doing relative to the best that you could be doing. It's a nice metric to use for improvement efforts. Actual XFactor values can be measured at the operation level (as each move is completed) or at the lot level (as each lot is shipped).

In FabTime, actual step-level XFactor is reported on the Moves Lot List data table as the total cycle time for that move divided by theoretical cycle time for that route step combination. Actual XFactor for shipped lots is not currently reported, though one can approximate it by taking the ratio of Actual Avg. Cycle Time to Actual Avg. Process Time in the data table on the Factory Cycle Time Trend and Pareto charts. Similarly, one can approximate operation-level XFactor from the Operation Cycle Time chart data tables.

Planned XFactors are also used in FabTime. A planned XFactor can be specified for each lot. Typically, this is set programmatically according to the lot's priority, though it could also be imported from the MES. Hot lots are planned to run with a lower XFactor than production lots.



If a lot's priority changes, the planned XFactor can also be changed.

FabTime uses the planned XFactors for the Lot Progress and Forecast charts, which look forward in time, and on the WIP Lot List chart, which includes an estimated ship date for each lot. By default, these charts use each lot's planned XFactor, multiplied by the theoretical cycle time for each step. If there is no Planned XFactor value entered for that lot (the default is zero), then FabTime will instead use planned total cycle time values stored for each step of each route.

The above-described charts also have an XFactor override that can be entered as part of the filter set on the left-hand side of the chart (see upper left-hand corner of the above screen snapshot). This tells FabTime to override the planned XFactor values, and use the value entered in the filter (multiplied by the theoretical cycle time for each step). This is helpful on the Lot Progress chart, for example, where you can do a what-if analysis on the future trajectory of the lot, depending on the lot's XFactor.

Naturally, the lot-level and override XFactors are only useful if you have accurate step-level theoretical cycle time data in place. Alternatively, you can still use the Forecast and Lot Progress charts to look forward provided you have step-level planned cycle time data by flow (though this approach will be a bit less accurate, since you won't be able to treat hot lots differently from regular lots).

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

Subscriber Discussion Forum

Issue 13.02: Capacity Planning

Bob Kotcher added a follow-on to his main article about capacity planning from the last issue. He said:

"I asked Advisory Industrial Engineer **Steve Brown** of IBM how they did capacity planning at their East Fishkill, New York fab—assuming that it wasn't proprietary, of course. Steve referred me to a paper (here) describing how IBM has developed a capacity planning system for their fab that combines queuing network modeling and mathematical optimization.

It is very impressive to see mathematical methods used on something as complex as a wafer fab. We need to add this to our list of wafer-fab capacity-planning options. Where does it stand vis-a-vis the others?

IBM's method requires a high commitment of resources, comparable to that of a discrete-event simulation (DES) model. IBM's model's outputs are clearly superior to those of static models, since the outputs include cycle times. A drawback is that a queuing network model may not capture some complex interactions involving things such as WIP control or rework rules as well as a DES model can. But mathematical modeling has a big advantage over DES modeling when it comes to runtimes. This is because each run is quicker, and each scenario must only be run once, whereas in DES modeling, each scenario may require twenty runs to get statistically valid results. The paper says that a scenario can be run in 15 minutes to 1.5 hours, whereas with IBM's previous DES model, a single scenario could take six hours or more.

In a demonstration of the power of incorporating cycle-time effects into capacity modeling, IBM says that its queuing model saved it US $30 million in capital avoidance compared to static models. Steve Brown can be reached at stevebn@us.ibm.com.

Downtime Reason Codes

An anonymous subscriber wrote: "We are discussing the implementation of downtime reason codes at our site. This is not something we have done previously, but we believe there would be value in analyzing our failures by a reason code that is assigned by the maintenance technician. Some of the questions that we've been considering are: 1) What is the best way to set up the infrastructure for the downtime reason codes; and 2) What is the appropriate level of detail for the reason codes?

Our maintenance manager has suggested that it is important to limit the reason codes to a relatively low number, since the logging will rely upon the operators and technicians to assign the appropriate reason code when logging an event. His recommendation was to create something on the order of 8 different reason codes that are general enough to capture any event. He also suggested making sure that one of them is NOT "Other" (because everything would end up going into that bucket). Do other newsletter readers have insights/suggestions based on their experience?"

FabTime Response: We agree it would be good to start with a limited set of choices, where "Other" is not one of the selections. Our guess is that setting these up will require some refinement. It might be useful to just try it with a few categories and then plan to adjust after several weeks go by, and you get feedback from people about the usefulness of the current set of choices. We also recommend using a short code that people actually enter, with a longer description associated with that code that can be appended / displayed on reports.

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

Reentrant Flow and Fab Cycle Time

We received a question a couple of months back from Michael Hair of L-3 Communications, via David Jimenez of Wright Williams & Kelly. Michael wanted to know if we had a clear way of explaining why reentrant flow makes it difficult to manage cycle time and WIP in a fab. We thought that this question deserved its own article.

Background

Reentrant flow is a well-known attribute of semiconductor wafer fabrication. The term reentrant flow refers to the fact that wafers revisit the same tools many times over the course of their time in the fab. As each new layer is deposited on the wafer, the same basic set of operations is repeated. This means that a lot can revisit the same toolgroup, and can sometimes be processed on the exact same tool, dozens of times. "Reentrant flow" thus refers to a process flow in which lots reenter the same tools.

Wafer fabs are notoriously reentrant environments. Reentrant flow is commonly seen on lists of factors that make running fabs difficult. But what is it exactly about reentrant flow that makes things so difficult?

Back to Fundamentals

Let's take a step back, and look at the fundamentals. As has been discussed many times in this newsletter (see Issue 6.05, for example), the three things that drive cycle time at the toolgroup level are:

- Utilization
- Variability
- Number of tools

Utilization isn't really affected by whether flow is reentrant or not, except in the sense that reusing tools for multiple visits increases utilization. But, assuming the same total volume of lots passing through a tool, it doesn't matter in a utilization sense whether the same lot comes through 20 times, or 20 different lots pass through.

Reentrant flow may actually be helpful in terms of number of tools. Consider a lot returning to the same tool group 20 times, instead of pulling the flow apart, and having the lot visit each of 20 different tool groups. You end up with more tools in the same toolgroup in the reentrant case than you do in the spread out case. Of course if you dedicate by layer, you lose that benefit. But still, in terms of number of tools per tool group, a reentrant line is most likely better than a linear line (for the same number of layers processed).

If it's not utilization, and it's not number of tools, then, as is usually the case when we're talking about fabs, it must come down to variability. Reentrant flow has a significant effect on variability, both in lot to lot process times and in time between arrivals. Process time variability is affected by having different recipes from different layers that run on the same tools. Process times for different layers can be quite different (take implanters, for example). From the tool's perspective, this drives up the coefficient of variation of the process times, and hence drives up cycle time.

Arrival time variability is affected by the fact that a tool may have lots coming from different places in the fab for different layers. So it's harder to smooth the flow of arrivals to a tool, because you're not managing arrivals from one location to the next, but rather managing arrivals from a number of locations. Also, reentrant flow means that tools feed themselves. A starvation event at a bottleneck toolgroup contributes to arrival variability back to that same tool group.

So, in a fundamental sense, it's the impact of reentrant flow on variability that causes it to drive up cycle time and WIP. But in a day-to-day sense, when we're thinking about managing fabs, the problem with reentrant flow is that it makes dispatching and planning more difficult.

Dispatching

Dispatch decisions in a reentrant environment are inherently more complex than dispatching decisions in a linear manufacturing environment. Although the basic flow within each layer tends to be similar, such that different layers are often feeding the same tools, this is not always the case. What this means is that we need to make dispatching decisions that consider where the lots are headed downstream. Otherwise, we risk overloading some toolgroups and starving others. We're also often deciding between processing lots at different layers. This can lead to a variety of sub-optimal situations:

- If there are setups when we change layers, we are incentivized to keep processing lots from the same layer for as long as we can, to minimize setups. This means that we're only sending lots downstream to a single location, rather than keeping WIP spread out across the fab. This causes WIP bubbles, which in turn contributes to arrival variability at other tools.

- Reentrant flow also complicates batching decisions. If lots from different layers can't be batched together, then it may be necessary to run partial batches, even when there are a large number of lots in the queue. Fabs often compensate for this problem early in the flow by starting WIP in batches of the same product, to fill the early batch tools. However, because of variability in the fab, these batches of like product don't always stay together throughout the flow.

- If it's late in the quarter, there may be incentives to pull lots that are late in their process flow out of the fab, to increase shipments. This can be done by prioritizing lots at later layers in the flow over lots at earlier layers in the flow. This, however, will lead to holes in the WIP later (and thus to potential bottleneck starvation).

Capacity Planning

Reentrant flow contributes to the complexity of capacity planning in wafer fabs, because calculating the required process time on each tool group requires adding up across all of the visits, and adjusting for yield loss between visits. This adding up across visits can be a source of errors in capacity planning spreadsheets.

Conclusions

The bottom line is that reentrant flow is an intrinsic and necessary part of wafer fabrication. It wouldn't be cost-effective (for most fabs) to somehow duplicate tools to create a linear flow. The fact is that we're depositing a series of very similar layers on each wafer, and it makes sense to use the same set of tools to do that. By having all of the (essentially similar) layers go through the same tools, we can do a much better job of keeping the tools busy than we could otherwise. And complexity levels in fabs are certainly not going to be decreasing any time soon.

In a sense of effective utilization, and in terms of number of tools per tool group, reentrant flow actually helps us (as compared with running the same long process flows, but not revisiting tools). But there's no question that reentrant flow also increases variability in wafer fabs (both in arrivals and process times). Reentrant flow also makes planning and dispatching significantly more complex than they would be otherwise.

But it does keep things interesting!

Closing Question for FabTime Subscribers

How do you manage reentrant flow in your dispatch rules?

Acknowledgements

Thanks to Michael Hair, Manager of Continuous Improvement at L-3 Communications, Narda Microwave - West, Folsom, CA, for posing the question that led to this article and to David Jimenez of WWK for passing along the question to us.

Further Reading

Here is a sample of research papers that specifically address reentrant flow.

■ S. X. Bai and S. B. Gershwin, "Scheduling Manufacturing Systems With Work-In-Process Inventory Control: Reentrant Systems," *OR Spektrum*, Vol. 18, No. 4, 187-195, 1996.

■ C. F. Bispo and S. Tayur, "Managing Simple Re-Entrant Flow Lines: Theoretical Foundation And Experimental Results," *IIE Transactions*, Vol. 33, No. 8, 609-623, 2001.

■ J. Y. Choi and S. Reveliotis, "Modeling and Performance Control of Capacitated Re-Entrant Lines (Extended Abstract)," Proceedings of the International Conference on Modeling and Analysis of Semiconductor Manufacturing (MASM 2002), Editors G. T. Mackulak, J. W. Fowler, and A. Schoemig, Tempe, AZ, April 10-12, 2002. 141-144.

■ P. Kumar, "Re-Entrant Lines," *Queueing Systems: Theory and Applications: Special Issue on Queueing Networks*, Vol. 13, 87-110, 1993.

■ Y. H. Lee and B. Lee, "Push-Pull Production Planning of the Re-Entrant Process," *International Journal of Advanced Manufacturing Technology*, Vol. 22, No. 11-12, 922-931, 2003.

■ Y. Narahari and L. M. Khan, "Performance Analysis of Scheduling Policies in Re-Entrant Manufacturing Systems," *Computers & Operations Research*, Vol. 23, No. 1, 1996, 37-51.

■ Y. Park, S. Kim, and C. H. Jun, "Mean Value Analysis of Re-Entrant Line with Batch Machines and Multi-Class Jobs," *Computers & Operations Research*, Vol. 29, No. 8, 1009-1024, 2002.

■ C. Rippenhagen and S. Krishnaswamy, "Implementing the Theory of Constraints Philosophy in Highly Reentrant Systems," Proceedings of the 1998 Winter Simulation Conference, Washington, DC, D. J. Medeiros, E. F. Watson, J. S. Carson, and M. S. Manivannan, eds, 993-996 . Full paper available from http://wintersim.org/pastprog.htm.

■ C. Veeger, P. Etman, I. Adan and J. Rooda (Eindhoven University of Technology), "Single-Server Aggregation of a Re-Entrant Flow Line," Proceedings of the 2010 Winter Simulation Conference, Modeling and Analysis of Statistical Methods (MASM) Track, 2010. Full paper available from http://wintersim.org/pastprog.htm.

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Cycle Time and Line Yield Improvement Manager
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