FabTime Cycle Time Management Newsletter

Volume 6, No. 1 January 2005

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 this version (6.2) include theoretical process time and cycle time x-factor on the moves lot list data table.

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Welcome

Welcome to Volume 6, Number 1 of the FabTime Cycle Time Management Newsletter! And Happy 2005! This is our 50th newsletter issue, and the start of our 6th year of publication. We've come a long way since the first issue was distributed to 33 people in 1999. This issue's distribution list of 1735 people represents a 52X increase. Thank you all for being part of the FabTime newsletter community!

This month's community announcements section consists mainly of a call for papers that we thought some of you might find of interest. In our FabTime software tip of the month we describe the use of the Dynamic X-Factor chart for looking at shift change effects. (Note that software users can subscribe to receive a short email containing the tip of the month only – just email Jennifer.Robinson@FabTime.com). This month we are in the rare situation of having no new subscriber discussion. We have listed the recent discussion topics below, however, and invite your comments for future issues.

In our main article this month we discuss the interaction between product mix and cycle time in a wafer fab. Specifically, we identify a number of reasons why increasing product mix may drive up cycle times. Although product mix itself is not a knob that people in the fab can just turn down to improve cycle time, we believe that exploring the underlying issues in more detail will suggest opportunities for cycle time improvement. We welcome your feedback.

Thanks for reading!—Jennifer

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Community News/Announcements

Change of Address

As announced previously, we are eliminating our Menlo Park, CA mailing address. Mail sent to that address will not be forwarded. If you need an updated mailing address for FabTime, send email to sales@fabtime.com. FabTime is based in San Jose and San Luis Obispo, CA.

Call for Papers – IEEE Compound Semiconductor IC Symposium

Over the last 27 years CSICS (formerly IEEE GaAs IC Symposium) has become the preeminent international forum on developments in integrated circuits using compound semiconductors such as GaAs, InP, GaN, SiGe and other materials. Coverage embraces all aspects of the technology, from materials issues and device fabrication, through IC design and testing, high volume manufacturing, and system applications. The IEEE Compound Semiconductor IC Symposium (CSICS) provides the ideal forum to present your latest results in high-speed digital, analog, microwave/millimeter wave, mixed mode, and optoelectronic integrated circuits. First-time papers concerned with the utilization and application of InP, GaAs, SiGe, GaN and other compound semiconductors in military and commercial products are invited. Specific technical areas of interest include:

- Innovative RFIC Device & Circuit Concepts
- Circuit Design & Fabrication
- Manufacturing Technology & Cost Issues
- CAD/CAM/CAT Tools & Techniques
- IC Testing & Methodology
- Packaging Technology
- Reliability
- Advanced Device Applications
- System Applications (commercial and military; e.g., wireless, vehicular, RADAR, medical, fiber system IC's)
- Optoelectronic and OEIC applications

The conference will be held October 30th to November 2nd in Palm Springs, CA. Abstracts may be submitted electronically up until May 9th, 2005. For more information (including submission address) see www.csics.org/.

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

FabTime User Tip of the Month

Look at Shift-Change Effects in Your Fab

Do you ever wonder if you are losing capacity during shift change? Or if certain shift teams handle the shift change better than others? There are a couple of different ways to explore this in FabTime. One way is to generate a Move Trend chart for the fab over a week or two, and use one hour (or less) for the period length. You can look for patterns, where hourly moves are high or low relative to the goal.

Another approach, which gives you some additional information, is to use the Dynamic X-Factor trend chart. The DXF chart shows total wafers divided by wafers currently running on tools. So, if the DXF is four, for example, then for every wafer in process, there are, on average, three wafers in queue. Over time, the DXF gives you a nice indicator of what your cycle time will be relative to your theoretical cycle time. But in the shorter term, DXF can dramatically illustrate shift-change effects. Think about what happens between, say, the hour before shift change and the hour of shift change. The total WIP in the fab (the numerator of DXF) stays pretty much the same. If the number of wafers running on tools (the denominator) goes down significantly, then you'll see a big spike in the DXF. To try this for your fab, simply do the following:

1. Go to the Chart list and Show Dynamic X-Factor charts (near the bottom of the list).

2. Click Go to generate the Dynamic X-Factor trend chart.

3. Change the period length to 1 hour, and include whatever normal filters you include when you look at WIP (e.g. only look at owner "mfg, eng", or filter the WIP to exclude crib operations and the like). Then press Go.

4. The resulting chart will move up and down over time (influenced by tool availability, etc.). But if you see periodic spikes that occur right at shift change, that's a sign that less WIP is being run on tools.

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

Presumably due to the holidays, we have no new subscriber discussion this month. Some open topics from the past few issues include:

- **Paperless cleanroom**s (Do people have them? Is the benefit clear-cut?)
- **300 mm cycle times** (Are they longer than 200 mm cycle times? If so, why?)
- Benchmark **cycle times for single-path toolsets** (What is a reasonable goal?)
- Setting **WIP targets** (How should these be set? How often should they be changed?)
- Managing **time constraints between process steps** (How should these be managed? How do you plan their capacity?)

If you have any thoughts to share on these, or other fab performance-related topics, we would be happy to hear from you. Your comments can be published with or without your name and company name, as you prefer.

Product Mix and Cycle Time

When we ask people about factors contributing to cycle time problems in their fabs, a response that we hear more and more frequently is "product mix." This makes sense to us. Having a degree of product mix will tend to make it harder to achieve great cycle time. But why is that, exactly? In this article, we discuss some of the reasons why having a high degree of product mix may drive up fab cycle times. We believe that simply understanding these reasons may suggest focus opportunities for high mix fabs that would like to improve their cycle time performance.

There are many different types of high mix fabs. There are high volume fabs that run a wide range of different products, scaling them up or down according to customer demand. Then there are low volume fabs that have short product cycles, and are constantly introducing new products. And of course, let's not forget the production fab that also runs development wafers. For all of these fabs, product mix may be driving up cycle times. When we talk about product mix in this article, we will consider two different aspects of a high mix fab. The first is the sheer number of different products. The second is the rate at which product life cycles change (variation in products). Both number of products and product life cycle changes contribute to variability in fabs. And no matter where you are on the upturn/downturn cycle, variability is still bad for cycle time. In the sections below, we will discuss some specific examples.

High Mix: Number of Products

Process Time Variability: If you have many different products in your fab, then you likely run many different recipes on each type of tool. Running different recipes (having different process times) on individual tools increases process time variability. And as we have discussed many times in the newsletter, increasing process time variability directly (and non-linearly) increases operation cycle times. The greater the number of different products in the fab, the more different recipes there are with potentially different process times.

Setups: Having many different products can lead to extra setups on certain tools. Setups take away standby time on these tools, and hence drive up utilization (where utilization is defined as Productive Time / [Productive + Standby Time]). And, as we have again discussed many times, increasing utilization on a tool (by reducing the amount of standby time) increases cycle time.

Batching: Having many different products, with different recipes, makes it harder to form batches at batch tools. Lots may wait longer to be put into a batch, especially for lower volume recipes, driving up cycle time.

Dispatching: In general, dispatching (deciding which lot to process next on each tool) is more challenging the more different products you have. Dispatch rules may need to include relative priorities of the different products, for example.

Reticle Management: The more recipes you have, the more of an issue managing reticles becomes. This can lead to extra queueing for lots, as they wait for the correct reticle to be located and brought to the proper tool.

High Mix: Short Product Life Cycles

Unbalanced Tool Utilizations: Changes in product mix can lead to unbalanced tool utilizations across different tool groups. For instance, you might have certain metal layers assigned to certain subsets of tool groups. A change in product mix could increase the loading on one of these sub-groups, while decreasing the loading on another. Because cycle time increases non-linearly with utilization, the sub-group with higher loading may have significantly

higher cycle time (especially if the tool is less than reliable). This tends to drive up cycle time. Obviously, tools can be reassigned in light of product mix changes. However, if the mix changes happen very rapidly, or very frequently, this is difficult to maintain.

Learning Curves: Changes in products, and the introduction of new products, require learning curves for both manufacturing and engineering (productivity learning and yield learning). Yield improvement activities during the yield ramp can themselves add variability, especially when they take away tools from production.

Holds: New products are likely be placed on hold more frequently than well-established products, and to stay on hold for longer periods of time. This hold time inflates shipped lot cycle times.

Benchmarking/Goal Setting: In a fab with short product life cycles, and hence relatively low volumes of each product run during the same time period, benchmarking results and setting cycle time goals can be difficult. There simply isn't enough data sometimes to draw conclusions about what is a reasonable cycle time to expect (especially in the presence of learning cycles). This makes it hard to set goals for improvement.

So What? I Can't Change the Product Mix in the Fab

It's all very well to outline potential interactions between cycle time and product mix. However, in most fabs, simply cutting down the amount of product mix isn't an option. Not for the people who work on the floor, at any rate. What you can do, however, if you are in a high mix environment, is look to the examples above for improvement opportunities. A few ideas are listed below.

Early Warning of Utilization Increases: If product mix changes lead to unbalanced tool groups in your fab, you could set up some type of early warning alert. If a toolgroup starts having actual utilization values significantly higher than planned, this would warn you to reassign tools from another sub-group, until the situation stabilizes.

Use of Product Families for Measuring Performance Data: For goal setting and benchmarking, you could identify families of like products, and use that more broad data to overcome shortfalls in the historical data for each individual product.

Reticle Management Systems: You might consider computer-based reticle management systems, in light of the potential for cycle time improvement. Does your reporting system let you break out tool unavailable time (or lot queue time) in enough detail to let you see time spent waiting for reticles?

Hold Reduction Programs: If you find that holds are a significant contributor to cycle time, you may benefit from an analysis of the reasons for holds, and/or a warning system to alert you before long hold times accumulate.

Setup Reduction Programs: The higher the degree of product mix in your fab, the more benefit you stand to gain from setup reduction programs.

Conclusions

If you work in a fab that runs many different products, and/or encounters frequent changes in product mix, you probably know instinctively that you could improve cycle time if you could somehow ratchet down the level of product mix. Unfortunately, in the presence of today's ever-increasing market differentiation and ever-shrinking consumer product life cycles, a reduction in product mix is not very likely to occur. Instead, we're likely to see an increasing proliferation of products, introduced more and more rapidly.

In this article we have identified several of the fundamental reasons why increasing product mix may increase cycle time. These include: increased process time variability; more setups; longer waits to form batches; more complex reticle management and dispatching; unbalanced tool utilization for smaller tool groups; learning curves for productivity and yield; and difficulty in setting goals from historical data. These suggest particular areas of focus for high mix fabs, to attempt to counteract these problems. Examples might include setup reduction initiatives and early warning indicators for tool groups that have higher than expected utilization.

Closing Questions for FabTime Subscribers

Are there other reasons why product mix drives up cycle times in your fab? What do you do to mitigate these issues?

Further Reading

- C.-S. Bong and K. V. Karuppiah, "Cycle-Time Reduction Under Product Diversity in Semiconductor Back-End Manufacturing," *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. 260-263.

- M. A. Dümmler, "Analysis of the Instationary Behavior of a Wafer Fab during Product Mix Changes," *Proceedings of the 2000 Winter Simulation Conference*, 2000. (All 1997 to 2003 WSC papers are available for free download from www.informs-cs.org/wscpapers.html).

- T. Miwa, "Automated Stepper Load Balance Allocation System Using On-line Subsequent Layer Processing Time Estimation," *Proceedings of the 2004 International Symposium on Semiconductor Manufacturing (ISSM 2004)*, Tokyo, Japan, 2004. This paper describes an automated stepper load balance allocation system developed to improve productivity in the photolithography process of high-product-mix/low-volume factories by balancing load distribution of tool constraint layers across steppers.

- A. M. Murray and D. J. Miller, "Automated Reticle Handling: A Comparison of Distributed and Centralized Reticle Storage and Transport," *Proceedings of the 2003 Winter Simulation Conference*, S. Chick, P. J. Sánchez, D. Ferrin, and D. J. Morrice, eds., 2003. (All 1997 to 2003 WSC papers are available for free download from www.informs-cs.org/wscpapers.html).

Subscriber List

Total number of subscribers: 1735, from 417 companies and universities. 25 consultants.

Top 10 subscribing companies:

- Intel Corporation (87)
- Analog Devices (79)
- Infineon Technologies (57)
- STMicroelectronics (53)
- Freescale Semiconductor (49)
- Philips (45)
- Micron Technology (43)
- Texas Instruments (40)
- AMD/Spansion (38)
- Seagate Technology (37)

Top 5 subscribing universities:

- Virginia Tech (10)
- Arizona State University (9)
- Nanyang Technological University (6)
- University of California – Berkeley (6)
- Georgia Tech (5)

New companies and universities this month:

- Abbott Laboratories
- China Electronics Engineering Design Institute
- Fabrication Owners Association
- Hamburg University of Applied Sciences
- Mentor Graphics
- Photonic Power Systems
- SFI Consulting
- Spectra, Inc.
- Syndex
- Tiger Venture Analysis
- University of Michigan – Ann Arbor

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.

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FabTime® Software Capacity Planning Module

Installation

For a fixed price, FabTime will:

- Identify the source of any additional data needed for the planning module.
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Do you need to answer questions like:

- Given a target product mix, do we need any new tools?
- Given the tools that we have, and the products that we are running, how many wafers can we expect to produce?
- Given our existing set of products and tools, what happens if the product mix changes? Where can we expect bottlenecks?

Are you tired of maintaining a standalone capacity planning spreadsheet?

FabTime's capacity planning module leverages the data already stored in the FabTime digital dashboard software, to make it easier to build capacity planning scenarios. The only required manual inputs are:

- Weekly ships per product.
- Product line yield percentages.

FabTime uses route information from the fab MES and calculates UPH data (tool speed) based on actual performance. FabTime also uses tool uptime performance to estimate availability (though this can be overridden). These inputs are used to generate predicted utilization percentages for each capacity type. Detailed intermediate calculations (UPH, tool productive time, tool rework percentage, etc.) are also available (an example for one tool is shown below). All outputs can be easily exported to Excel.

Capacity Planning Module Benefits

- Eliminate the need to maintain offline capacity planning models.
- Automatically update capacity planning data to reflect new conditions (process flows, tool uptime characteristics).
- Quickly run scenarios to anticipate (and avoid) bottlenecks caused by product mix changes.

C Type	Output	Value	Notes
1XStep	Rework Moves/Week	21	2004-09-06 10:00:00 to 2004-11-15 10:00:00
1XStep	Total Moves/Week	12310	2004-09-06 10:00:00 to 2004-11-15 10:00:00
1XStep	Rework Ratio	0	Rework Ratio = Rework Moves / Total Moves.
1XStep	Productive%	61	2004-09-06 10:00:00 to 2004-11-15 10:00:00
1XStep	Availability%	76.26	Availability = Productive% + Standby%.
1XStep	Historic Utilization%	79.99	Utilization (Mfg efficiency) = Productive% / Availability%.
1XStep	Productive(Rework)%	0.1	Productive(Rework)=Productive% * ReworkRatio.
1XStep	Net Availability%	76.15	Net availability% = Availability% - Productive(Rework)%.
1XStep	Arrivals (Units/Hour)	79.36	Based on total plan WGR=2025
1XStep	Tool Quantity	8	1XStep#1 ... 1XStep#8
1XStep	UPH	15.02	UPH = (TotalMoves/ToolQty) / (Productive% * 168)
1XStep	Required Hours/Day	126.84	Required hours = 24 * HourlyArrivalRate / UPH
1XStep	Predicted Utilization%	86.75	Util = 100 * ReqdHours / (24 * NetAvail * ToolQty / 100)
1XStep	Max WGR	2334.22	MaxWGR = PlanWGR / PredictedUtilization
1XStep	Historic WGR	2457.8	(Non Rework Moves) / (OperationCount / ProductCount).