FabTime Cycle Time Management Newsletter

Volume 5, No. 1 January 2004

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 current version (5.6) include filter comparison operator support (<=, <, >=, >) to specify ranges in filters, and new average inventory age alerts for operations, areas, and tool groups.

Editor: Jennifer Robinson

Contributors: Daren Dance (WWK); V.A. Ames (Productivity System Innovations).

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Welcome

Welcome to Volume 5, Number 1 of the FabTime Cycle Time Management Newsletter, and Happy New Year! It seems incredible that we're beginning our fifth year of publication. Thanks for staying with us. Hopefully 2004 will bring the long-anticipated rebound for the semiconductor industry. We would also love for it to include an expansion of the subscriber community for the newsletter, which has leveled off over the past few months at just over 1400. If you could help by forwarding a copy of the newsletter to people who you think might like to subscribe, we would very much appreciate it. We've also modified the format of this PDF version of the newsletter, to make it easier to print and share.

Subscriber discussion topics for this month include responses to Issue 4.09 (WIPHours Metric) and 4.11 (Cycle Time and Factory Size). This month's main article is about the interaction between cycle time and yield. We've always cited yield improvement as a potential benefit from cycle time improvement, and people we talk with about this generally agree. However, because the actual data tends to be proprietary in nature, references on this topic are scarce. Therefore, we've decided to open the topic for discussion here, and summarize a few references that are available. We hope that you'll find the discussion interesting.

Thanks for reading!—Jennifer

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Community News/Announcements

Volume 4 of the Newsletter Now Available from Amazon

The complete set of issues from Volume 4 (last year) of FabTime's cycle time management newsletter is now available for purchase from our Amazon zShop (www.amazon.com/shops/fabtime). The cost for the set of 11 issues is $74, a 33% discount from the single issue price of $9.95/issue. The cost for the complete set of all past issues (39 total) is still $195. The past issues are sent electronically, via email. However, if you purchase the complete set, we are happy to also send them to you on a CD. There is no charge to subscribers for receiving the current issue of the newsletter. Past issues, however, are only available from our Amazon shop.

Alternate Email Addresses

Every month we lose a certain number of subscribers due to their email addresses bouncing. When someone's address bounces two months in a row, we assume that they are no longer at that address, and we remove the address from the subscriber list. Last month (December) we had to drop a record twenty-nine subscribers. Because we hate to lose any of you as you change jobs, etc., we would like to suggest that you think about giving us an alternate email address, which we'll use in the event of your primary address not working. As always, we guarantee that we'll never disclose any of your addresses outside of FabTime. If you're interested in this, just send the address to newsletter@fab-time.com (or reply to the newsletter issue), and we'll keep it for backup. Thanks!

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

FabTime User Tip of the Month

View Shared Home Page Tabs

FabTime version 5.6.1 includes a new feature that we wished to bring to your attention. Users can now share individual home page tabs if they have permission from the system administrator. Once someone shares a home page tab, all users can access that shared page. This allows, say, your fab manager to set up a shared page that highlights the current top-priority performance metrics for your site. Or, a module manager might update a home page tab to show critical tools for this week.

To view shared home page tabs, select the person who's home page you wish to see from the "FabTime User" drop-down in the upper left-hand corner of your home page (just below the red "Home" button), and press "Go". This causes FabTime to update the list of charts shown in the "Home Page Tab" drop-down list, to show the home page tabs shared by that user. Pick the home page tab of interest from the list, and press "Go". FabTime will display your selected home page tab. You can click through to view charts and auto-refresh the page, as usual, but you will not be able to make any changes to which charts are displayed. To return to your own set of home page tabs, simply return to the "FabTime User" drop-down, select your name, and press "Go".

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

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Subscriber Discussion Forum

WIPHours Metric (Response to Issue 4.9)

An anonymous subscriber wrote: "I wanted to respond to Issue 4.9, but was unable to until now. The WIPhrs metric that was developed in the body of the newsletter made me think of uses and applications of forward looking metrics. I have begun work adapting a similar approach to operations at my fab. In the process it occurred to me that this tool could be used as a mfg policy in conjunction with a future CT indicator. It's all a matter of shifting your point of view.

This approach involves calculating a WIPhrs metric for each operation on the line. This could present a problem with tools that share processes and have a large amount of re-entrant flows. In that case one could use a weighted average of WIP at that operation as the decision point for number of tools to allocate. After the WIPhrs metric is developed, each area of tool clustering could then use all down stream (directly down stream) WIPhrs values to determine where and what to produce. Say you pareto those values out for each tool grouping and add a goal of 12 hrs. You would run what operation has the least amount of WIPhrs. If there are no operations with WIPhrs below goal then the tool sits idle or completes some PM work. In this way the line will find a natural state of equilibrium and "WIP bubbles" will not be perpetuated or created. This system then allows mgmt to focus on issues that directly affect CT (availability, utilization, etc.)

If you couple this with a CONWIP style lot dispatching system (as one lot leaves the fab one lot enters) you have just created yourself a nice little pull system (without all of the mess that comes along with the phrases "Lean" or "Pull"). I'd like to hear your thoughts on my approach as well as anything your readership has to say."

FabTime Response:

As we defined it in Issue 4.09, WIPHours is equal to the expected number of hours required to complete the WIP that's in queue for a given toolset, taking into account the expected short-term availability of the toolset, and the number of tools that are currently up and ready to process. You can calculate this by operation, but as you mentioned, you have some problems with shared tools, deciding how many tools you say are available for each operation.

We think that conceptually the idea of using a metric like this to help the line to find a natural state of equilibrium makes sense. We're just not sure how the details would work to implement it, when looking at WIPHours by operation. It makes sense that you could have a 12-hour goal for the overall WIPHours value for a toolset. This says, "I want to be able to process all the WIP in front of this set of this set of tools during this shift". But we don't think that you can look at WIPHours by operation and talk meaningfully about that same 12-hour goal, since the WIPHours values are additive across the operations. For example, you might have 3 WIPHours of Operation A, and 10 WIPHours of Operation B, for a total of 13 WIPHours for the toolset. You're already above the overall goal for the toolset. You could have different goals for the different operations, but then you get into an allocation problem in the short-term. We think that a numeric example would help in understanding and evaluating this idea, and we'd be interested to hear how your work on this topic proceeds.

Cycle Time and Factory Size (Issue 4.11)

Daren Dance (WWK) wrote in response to last month's article about cycle time and factory size: "Thanks for the interesting discussion and the use and

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acknowledgement of Factory Explorer. In my own (distant) past – I also observed that cycle time did not track utilization very closely –-however, hot lot cycle times generally do go down at lower utilizations. This illustrates the point that cycle time is as dependent on the management of an operation as it is on the factory physics."

V.A. Ames (Productivity System Innovations) also sent remarks about the last issue. He said: "The methodology you describe in your main article could be called "bottleneck management" and is a useful tool in any factory, large or small, especially when it comes to running a factory with a high product mix.

An Overall Equipment Efficiency (OEE) measurement for each tool can really help determine if a tool should be shut down or not. It is much more efficient, and therefore, cost effective to operate one tool at 70% OEE than two tools at 35%.

With more fabs going to high volume, high mix production, bottleneck management is becoming more difficult. As the different product starts vary from week to week the true bottleneck(s) in the fab may move around from day to day. This makes having the right number of tools in production even more difficult to determine. Having any tool sit idle costs money. Reducing cycle time and being the low cost manufacturer in this environment is the challenge many are facing today and even more so in the future, no matter what the factory size.

I guess this is why TPM and Lean Mfg was developed in the first place, and is what keeps us consultants in business..."

Cycle Time and Yield Loss

Introduction

When we think about the benefits from cycle time improvement, one that we usually list is yield improvement. It makes intuitive sense to people that if wafers spend less time waiting in queue, they'll have less opportunity to become contaminated, and yields will improve. Scrapping wafers also increases variability in the line, which drives up cycle time. Most people we've talked with about this agree, and many have indicated that they have internal data to support this conclusion. For example, they get better yields on their higher priority lots, which have shorter cycle times.

However, because yields are usually sensitive information, we've found very few publications that support this conclusion. We've heard wide-spread anecdotal evidence, and intuitive agreement, but seen very little in the way of numbers. In this article, we will summarize the publications that we have seen, and discuss some potential ways to quantify this effect. We'll ask you, our subscribers, to share with us any non-confidential data or publications or conclusion that you might have on this topic, and we'll include any results in the next issue. We're happy to publish your comments anonymously, if you prefer, to protect your confidentiality.

Literature Review

We've been collecting papers related to fab cycle time and capacity for more than 10 years. Of the papers that we've collected, only a few (described below) explicitly discuss the relationship between cycle time and yield. One of the papers (the first

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listed) actually finds the correlation between yield and cycle time to be insignificant, although the other four support the idea that improving cycle time will improve yields.

■ S. P. Cunningham and J. G. Shanthikumar, "Empirical Results on the Relationship Between Die Yield and Cycle Time in Semiconductor Wafer Fabrication," IEEE Transactions on Semiconductor Manufacturing, Vol. 9, No. 2, 73-277, 1996.

The authors of this paper perform a lot-by-lot analysis of die yield and cycle time data from four volume semiconductor manufacturing facilities, and conclude that the correlation coefficient between die yield and cycle time is often statistically insignificant. The also feel that "statistical models regressing die yield on cycle time are poor, and thus should not be used as the basis of decision-making in production control."

■ P. Nag, W. Maly, and H. J. Jacobs, "Simulation of Yield/Cost Learning Curves with Y4," IEEE Transactions of Semiconductor Manufacturing, Vol. 10, No. 2, 256-266, 1997.

This paper describes a prototype of a discrete event simulator, developed as part of the first author's Ph.D. dissertation, capable of simulating defect related yield loss and manufacturing cost as a function of time. The model estimates yield and cost from a variety of parameters, one of which is cycle time. It should be noted, however, that the relationship between yield and cycle time is used as an input for this model, rather than being a data-driven output.

■ K. Srinivasan, R. Sandell, and S. Brown, "Correlation between Yield and Waiting Time: A Quantitative Study," Proceedings of the Seventeenth IEEE/CPMT International Electronics Manufacturing Technology Symposium: Manufacturing Technologies - Present and Future, Austin, TX, 65-69, 1995.

This paper describes a SEMATECH study that looks at the effect of cycle time reduction and environmental cleanliness improvement on yields in wafer fabs. The study includes a methodology for determining the impact on total process yield from reducing queue times. The methodology is explored using a SEMATECH model of a logic fab. However, no actual historical data appears to be included.

■ L. M. Wein, "On the Relationship between Yield and Cycle Time in Semiconductor Wafer Fabrication," IEEE Transactions on Semiconductor Manufacturing, Vol. 5, No. 2, 156-158, 1992.

In this paper, the author (an MIT professor) derives a relationship between the average amount of time wafers spend in the fab and the mean production rate of nondefective die. He assumes that the number of defects per die is a Poisson random variable whose mean varies linearly with the amount of time the wafer spends in the fab. Here again, the relationship is more theoretical than based on actual historical data for a particular fab.

■ M. Yu, W.-C. Chang, C. Chen, Y.L. Hsieh Chen, C. Y. Hsieh, and C.-K. Wang, "Development of Waiting Time Control System for Yield Enhancement and WIP Management," Proceedings of the 2002 International Symposium on Semiconductor Manufacturing, Tokyo, Japan, 2002.

This paper is focused on distinguishing the impact of different factors on yield, so that causes of failure can be identified and yield improved. The paper specifically looks at the ways in which queue time influences yield, and references manufacturing data from TSMC that shows that yield can be improved through effective waiting time management in critical stages. The control system used in the study also resulted in significant reductions in rework rate (40%).

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The above paper references two other papers as describing the correlation between high yield and low cycle time, though we haven't seen these papers ourselves:

- D. Meyersdorf and T. Yang, "Cycle time Reduction for Semiconductor Wafer Fabrication Facilities," IEEE/SEMI Advanced Semiconductor Manufacturing Conference, pp 418-423, 1997.

- W.-C. Chang, M. Yu, R. Wu, C. Chen, J. Chen, C.Y. Hsieh, and C.K. Wang, "Yield Improvement through Cycle Time and Process Fluctuation Analyses," Semiconductor Manufacturing Symposium, 2001 IEEE International, pp 267–270, 2001.

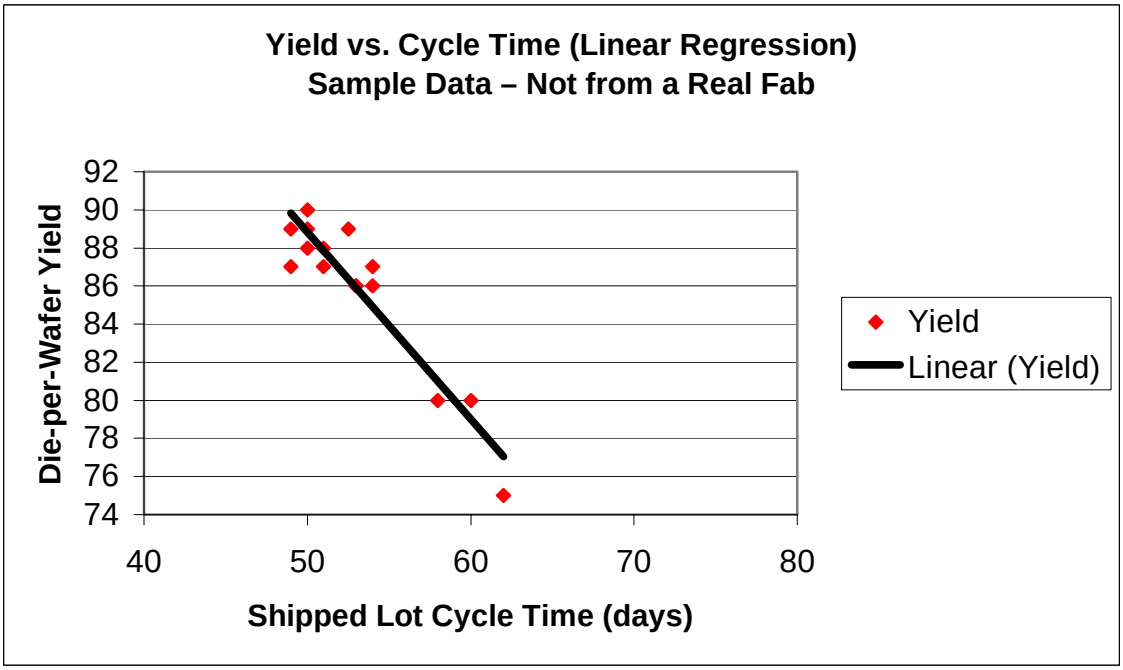
Quantifying the Relationship between Cycle Time and Yield

So, how would you quantify the relationship between cycle time and yield in your fab? If you have a sufficiently high volume of a particular product, you could look for correlation between the cycle time (or the total queue time) and die-per-wafer yield of individual lots of that product type. Of course other factors might affect this die-per-wafer yield (processing of the lot on particular tools, for example), but with sufficient data (say, at least 25 lots), you can get a sense of whether or not there's a relationship. We suggest as a first pass plotting yield vs. cycle time (or total queue time) in Excel, using the XY (Scatter) chart type, and then right-clicking on the data series in the chart and selecting "Add Trend Line." Add a linear regression trend line, and see if, or how much, the line slopes. An example (NOT from real data) is included below. The authors of the TSMC paper described above do something like this, but they prepare different graphs for each stage of the production line, and look at yield vs. queue time within that stage. Of course the relationship might not really be linear for your fab, but it's a good starting point.

For a good general reference about how to graphically display data to maximize understanding, see the book:

- E. R. Tufte, "The Visual Display of Quantitative Information," Graphics Press, May 2001.

For a less detailed approach, some fabs compare the cycle time of their regular lots with the cycle time of hot lots that follow a similar process flow, and derive a relationship from that. For example,



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suppose that the average regular lot cycle time for lots shipped during December was 42 days, with average die-per-wafer yield of 80%, and the average hot lot cycle time for the same period was 28 days, with average die-per-wafer yield of 90%. We can hypothesize that the 33% (6 weeks down vs. 4 weeks) decrease in cycle time contributed to the 10% increase in line yield. It would require data from other months, other products, or other fabs to strengthen the conclusion. (Please note that these numbers are completely made up, and are not representative. We would expect the actual values to vary according to type of fab.)

There are certainly other more detailed approaches that could be used to explore the relationship between cycle time and yield. Our purpose here is to state that there probably is a relationship, and that you can get a feel for what that relationship is for your fab without having to gather too much data. Quantifying this relationship for your fab may help you to justify cycle time improvement efforts (since the impact of yield improvements on the bottom line can be substantial).

Summary

We think it likely that reducing cycle time will improve yields. The less time wafers spend in the fab, the less opportunity they will have to be contaminated or damaged. Scrapping wafers also increases variability in the fab, which increases cycle time. Because of the proprietary nature of yield data, we've only seen a few formal publications to this effect. In this issue we've summarized these publications, and discussed ways to measure the impact of cycle time on yield loss. If any of our subscribers have anything to add on this topic, we'll include further discussion in the next issue.

Closing Questions for FabTime Subscribers

Has your company published any results regarding cycle time and yield? Is this something that you measure? How do you measure it? Have you observed a correlation between cycle time improvement and yield improvement? If you send us your comments, we will include them in the next issue. We will NOT include your name and company name unless you specifically tell us that it's ok to do so.

Cycle Time in the News

■ D. Pringle, J. Drucker, and E. Ramstad, "Cell Phone Makers Pay a Heavy Toll for Missing Fads." This recent (September 26th) Wall Street Journal article discusses the increasingly short product cycles for cell phones. Companies that miss fads such as camera phones or color screens or smaller handsets can lose market share quickly. Qualcomm, for example, got out of the handset market altogether, because they "couldn't keep up with the cycle times." By contrast, manufacturers that can jump on these trends, and release new models quickly, command higher prices, and gain market share. The fastest Chinese manufacturers are replacing some models after only 6 months, compared with previous US product cycles of 2 years or more.

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Subscriber List

Total number of subscribers: 1426, from 374 companies and universities. 28 consultants.

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- Motorola Corporation (58)
- Infineon Technologies (44)
- STMicroelectronics (44)
- Philips (41)
- Seagate Technology (41)
- Micron Technology, Inc. (39)
- Advanced Micro Devices (35)
- Texas Instruments (33)
- Agere Systems (32)

Top 3 subscribing universities:

- Arizona State University (12)
- Virginia Tech (7)
- University of California – Berkeley (6)

New companies and universities this month:

- AFPD Pte., Ltd.
- austriamicrosystems
- Bourns
- CSMC
- DenseLight Semiconductors
- e2v Technologies
- FormFactor
- Global Communication Semi., Inc.
- Stryker Leibinger
- TianJin University

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.

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Do you achieve the best possible cycle time?

- Where are the cycle time opportunities in your fab?
- Are your cycle time goals appropriate for your fab?
- Do your standard operating practices cause cycle time?

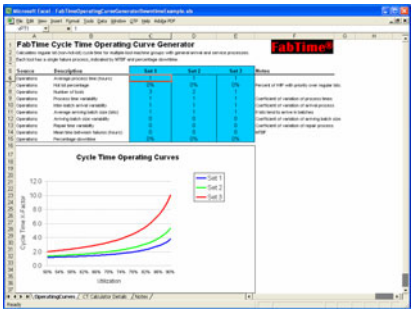
FabTime provides cycle time management tools and training for wafer fabs. Our consulting services start with a 2-pronged approach.

Option 1: Data-Focused Analysis

If you need data to analyze your current cycle time issues, we can read your historical data into our cycle time management software, and highlight specific opportunities. The project includes cycle time analysis, cycle time benchmarking, and an on-site review of results.

Option 2: Site-Focused Training

If you need help with cycle time goals and metrics, we offer a site-focused session of our 2-day cycle time class. On the first day, we cover fundamental cycle time relationships and the calculation of cycle time goals using spreadsheet tools. On the second day we target your most pressing issues, including your current cycle time goals and performance metrics.



"We derived great value through gaining understanding of the use of, and underlying concepts behind, the FabTime Operating Curve Generator and the Route Cycletime Entitlement Calculator."

Scott Conklin
Sr. Director, Wafer Manufacturing
Seagate Technology, Inc.

Benefits

- Identify key causes for your fab's cycle time performance.
- Understand and predict your fab's cycle time entitlement.
- Choose metrics that promote cycle time reduction.

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