FabTime Cycle Time Management Newsletter

Volume 8, No. 10 December 2007

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 this month include the ability for end users to hide data table columns and save their preferred data table configuration for each chart.

Editor: Jennifer Robinson

Contributors: Troy Sterk (TriQuint Semiconductor); and Stephane Prioux, Benjamin Laude, Irawan Bahtera and Jerome El Khoury (all from STMicroelectronics)

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Welcome

Welcome to Volume 8, Number 10 of the FabTime Cycle Time Management Newsletter! This month we've been fortunate to be asked to deliver cycle time management courses to two new companies, as well as to start software installation at our 15th customer site. We've also been adding lots of new features to the software, mostly based on suggestions from our customers. In this month's newsletter we are pleased to announce a FabTime case study that was published by one of our suppliers. Our software tip of the month is about displaying chart data tables directly on FabTime home page tabs. We have a plethora of subscriber discussion in this issue, including a response to an ongoing topic about modeling cluster tool behavior, two responses to a question about managing combined production and development fabs, and two detailed responses to last month's article about cycle time benchmarking. We hope that you find food for thought in these contributions, and that they may inspire some of you to voice your thoughts, too.

In our main article this month, written by Frank Chance, we propose a fab cycle time improvement checklist. The idea is to help codify cycle time improvement practices, so that they become repeatable. The seven items in the checklist include identifying baseline cycle time metrics, finding metrics that indicate current and future cycle time problems, and looking for root causes. These, and other steps, are discussed below.

As the year draws to a close, we would like to thank all of you for subscribing to the newsletter. We are especially grateful to those of you who have taken the time to send in contributions to our subscriber discussion forum, and to those of you who have forwarded the newsletter to your colleagues. The newsletter would not be nearly as relevant with your help. Thank you!

FabTime would like to wish all of you a joyful holiday season, and a healthy and productive 2008—Jennifer and Frank

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Community News/Announcements

FabTime EditMe Case Study

FabTime is featured in a case study by EditMe, the WIKI provider that we use for managing our customer support websites. The article discusses our requirements (ability to securely manage multiple different customer support sites), and our success with EditMe's solution. You can read the entire case study at www.editme.com/CaseStudyFabTime. We do recommend EditMe, if you need to set up secure, collaborative, hosted websites.

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

FabTime User Tip of the Month

Display Chart Data Tables on your Home Page

Have you ever wanted to add a data table, instead of a chart, to your FabTime homepage? Maybe you want to see a list of hot lots, and be able to click through quickly to the lot history chart for each. Maybe you like the Line Summary chart, and would like to have that updating on your home page. Maybe you want to see a list of downtime events that fall under a particular reason code, complete with MES comments. Now, if your site has user interface 717u or later (Patch 89), you can add data tables to your home page. To do this:

- Configure the data table that you want on the associated chart detail page – it's fine to also be displaying the chart image on the chart page. Hide columns that you don't want included in the data table, if applicable (this requires Patch 90), and confirm that you have your target number of rows displayed, and the proper sorting of the data table.

- Add the chart to whatever home page tab you like (using the "Add" button in the upper left corner of the screen).

- On the home page tab, click the tiny "table" link above the chart. FabTime will display the data table for the associated chart, with scroll bars (if applicable) so that you can scroll up or down within the table.

- To drill down from the home page data table, just click on any of the gray links displayed. This will take you away from the home page, and to whatever chart page you selected.

- To get to the detailed chart page associated with a home page data table, click the "ChartPage" link above the data table (on the home page).

- To switch from data table view back to chart view on the home page, click the "Chart" link above the data table.

Note that for large data tables, such as the line summary chart, you may want to have a special home page tab in which you display the data tables in a single, wide column. Image size and number of columns are now specific to each home page tab. You can have one tab that has larger boxes for data tables, and another that uses smaller boxes for displaying charts (or vice-versa, if you like). We hope that you'll find the ability to display data tables right on your home page useful.

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

Issue 8.06: Cluster Tools

In response to an earlier question from **Bob Kotche**r about modeling the behavior of cluster tools, an **anonymous subscriber** wrote: "We have several Enduras that have two etch chambers, two cool chambers, a Ti chambers, two Al chambers, and a TiW chamber. When one Al chamber is in kit change, the wafer sequence through the remaining chambers for a recipe that uses: etch, Ti, Al, cool, TiW, is easy to predict. When both chambers of Al are on line, predicting the wafer sequence through the tool has been impossible, even with the equipment vendor's software support. I think many times that when a supplier says something is "proprietary", the really mean "we don't really know"."

Issue 8.09: Managing Combined Production/Development Fabs

Ryan Carlson of Seagate Technology submitted the following question for last month's subscriber discussion: "How do fabs that run both development and production wafers maintain learning with fewer moves devoted to R&D lots?"

We received two responses to this question. First, we had the following response from an **anonymous subscriber**: "From my experience (since 1982) most IC Fabs run some portion of WIP for R&D or development. Keep in mind that foundry Fabs run about 40 % of their product runs as only 100 wafers or less. Therefore, in today's factories, cycles of learning based on product data are extremely difficult - either the product mix is very high with multiple technologies or datasets are very small and intermittent. The answer is short-loop monitors with electrical test structures.

I work in an extremely small WIP Fab (~100 12 wafer lots with less than half available for processing at any one time). We use short-loops of special mask sets for yield learning. The trick is to simulate the product with special test structures. We use small lots of 4-8 wafers to minimize cycle time and minimize the number of masks to get quick electrical results (we have in-fab probe systems). Our technology is CMOS circa 1992 so our yield models well with just gate area and number of levels of metal. Therefore we run a gate monitor of various capacitors tested post salicide. A metal serp/combs lot (4 wafers single metal mask) is tested weekly. We also run via and contact chain monitors. Electrical CD's (and Rsheet) for gate/salicide and metal interconnect can be performed on an array of resistors with a constant number of squares. Test structures on product masks generally don't have sufficient area to capture true defect levels. Drop-ins in the scribe lane are also used but not for defect detection. Our fab has mostly one-of-kind tools so that tool commonality studies don't work. Our WIP is so small that the e-test dataset is very small and infrequent.

Our number one problem is intermittent excursions. It's very hard to run controlled experiments when your problem only occurs 40% of the time! In our experience the single layer monitor wafers run through equipment for qualification tests are too far removed from the conditions of actual product. The key to increasing the number of yield learning cycles is to get commitment from management to run "non-product" in the line. It takes a portion of your factory capacity to learn how to improve your product. On-product optical defect correlations to product yield are very hard because the number of non-fatal defects is huge. The capture rate of fatal defects is very poor for the cost of the tools and time it takes. That's why electrical fault-based test structures are critical."

Second, **Troy Sterk** from TriQuint Semiconductor wrote: "In regards to Ryan Carlson's question. We are a low volume, high mix GaAs Fab. We have contracts with the government to develop next generation technologies. So our R&D is mixed with production since we don't have a dedicated R&D Fab. With low volume, cycles of learning are few so we routinely split lots on production product to test process changes. We have very sophisticated tracking systems to flag the product through the line and quarantine it in a Material Review Area so we don't ship experimental product without formal release of the change through our review board. This allows us to compile enough data in a low volume shop to achieve statistical relevance. We use some very intuitive GUI based data mining tools to look for correlations as well.

All of our R&D products run on the exact same tools we use for normal production with the necessary controls through PFMEA's and Process Engineering controls to prevent the new processes from impacting the current release processes. For the most part, the steps used to build a new technology are mostly the same. Unique steps usually require a few new tools. The whole new process is run through a formal release plan including reliability prior to release. But, along the way production tools and operators run the product, allowing time for training and enough product to learn corners of the process / product interactions. Using DOE techniques for validating product/process sensitivity to normal process variations allows us to run fewer products while still achieving statistical significance. Also, modeling at the device level allows us greater confidence when releasing new parts without tons of wafers. We need to keep the excess experimentation to a minimum to keep the costs in line, but enough wafers through the process to validate the concept. Using the above tools affords us the opportunity to have great new processes / products and manage the cost."

Issue 8.09: Cycle Time Benchmarking

In our main issue last month, we asked a series of questions about how fabs benchmark cycle time. We received two detailed responses.

Troy Sterk from TriQuint Semiconductor said: "For the cycle time X-Factor, you noted a few measures for determining X factor. We use average process time for each step along with the set up time for the operator to load and unload the lot as measured by an Industrial Engineer with a stop watch for a typical (average) product by technology. We sum all the steps for the product which accounts for the specific recipe differences at each step. For any particular step on a single wafer processing tool, we include the entire lot processing time into the theoretical time in conjunction with the load and unload times. Remember, we use the X-Factor to benchmark with other Fabs so it needs to be representative of the product mix by technology, not specific to small idiosyncrasies of product to product variation like # of Steppers Shots on this part vs. another part. You can drive yourself crazy with that level of detail for a high level metric like X-Factor. Continuous improvement means you should be driving the metric down and using it to benchmark yourself against your competition as well as the world's best.

We also received the following detailed set of responses from **Stephane Prioux, Benjamin Laude, Irawan Bahtera and Jerome El Khoury** (all from STMicroelectronics):

Q. How does your fab measure X (theoretical CT)? Do you use hand-carry lots, or process time estimates? Do you include travel time? Are your measurements lot-size dependent?

A. Our theoretical CT called CTTH is calculated in "real time" by our MES system (automation + CAM consolidation) and loaded on a weekly basis to our shop floor scheduling tool. This CTTH is the sum of all "added value" steps so the transport time is excluded. We are not taking into account lot size, thus resulting in an "underestimated" CT

Q. Have you ever compared DXF values to shipped lot cycle time X-factors for your fab? Were they representative?

A. DXF is not computed for our fab.

Q. How does your fab measure shipped lot cycle time (through electrical test? die sort?)?

A. The shipped lot ct is calculated from start to end of electrical test. The EWS (die sort) is counted separately.

Q. Does your fab use a dynamic version of DPML, or do you only compute DPML for shipped lots?

A. DPML is only computed for shipped lots on a monthly basis for action plan and on a bi-weekly basis for review. The "real time" fab performance indicator remains "moves".

Q. Does your fab use X-factor, DPML, or both?

A. We are using both. But while DPML remains our CT performance indicator, the X-Factor is used to better understand the weighting of each CT detractor (Process, Queue & Transport, Hold and Rework time elements) and build the action plan.

Q. Do you know the theoretical cycle time per mask level in your fab?

A. Yes but we are not considering this parameter to setup our cycle time targets."

FabTime Response: We very much appreciate Troy Sterk and the STMicroelectronics team for taking time to provide detailed answers to these cycle time benchmarking questions. Has their feedback inspired anyone else to jump in?

If you have a response to any of the above topics, or would like to submit a new question to the subscriber community, please send you feedback or question to newsletter@FabTime.com.

A Fab Cycle Time Improvement Checklist

Introduction

In this article, we propose a fab cycle time improvement checklist. We haven't seen a checklist like this before, and we believe that one would be a useful addition to the cycle time improvement toolkit. When we use checklists, we codify our practices so that they become repeatable. In our daily work at FabTime, we use a variety of checklists -- there is a checklist we follow when we release an update to our software, there is one we follow when replying to a sales prospect, there is even a checklist that we follow when sending this newsletter. Certainly there are areas of human endeavor that appear immune to checklists; for example the creative works of art ("Today's tasks: 1. Buy brushes. 2. Paint masterpiece in Sistine Chapel") or mathematics ("1. Find pencil. 2. Prove Fermat's last theorem."). But for cycle time improvement, we think that a checklist is in order.

We have assembled the following seven-item checklist:

1. Choose bottom-line metrics.
2. Choose leading metrics.
3. Decide: Do we focus on historical or immediate data?
4. Choose red-flag metrics.
5. Drive the process via the morning production meeting.
6. Check for common root causes of cycle time.
7. Tackle the details.

Each of these items is discussed in more detail in the sections below.

1. Choose Bottom-Line Metrics

This step is, at its core, a discussion about scoping the problem and admitting that some problems are outside of our control. First we must decide whether we are concerned about cycle time or on-time delivery, though the two are certainly related.

If our focus is on on-time delivery, we must establish which delivery date we are working against. In our experience, there are often 2-5 different due dates for each lot stored in various corporate databases. We can spend considerable time going around in circles if we select the wrong one. Since we're talking about improving fab cycle time, we of course need a due date and delivery point that is relevant for the fab. To be able to roll up the on-time statistics, we need to know if the summaries will be based on the percentage of lots that shipped on time, or the percentage of wafers that shipped on time, or some other grouping.

If our focus is on cycle time, we need to define our cycle time metric. Saying that we are measuring shipped lot cycle time often isn't enough to uniquely define the measurement. For example, we need to confirm:

- Where (at which operation) does the fab cycle time clock start?
- Where does the fab cycle time clock end?
- Do we exclude customer holds or extended holds in a store or wafer bank?
- Do we exclude anything else?
- Are we measuring all lots, including development lots? Or only lots with a customer due-date attached?

Once we have chosen the conditions for our bottom-line metric, we must ensure that the lower level metrics discussed below are defined in a parallel fashion. For example, if development lots are excluded from the shipped lot cycle time metric, they should also be excluded from the fab turns metric.

Whatever bottom-line metrics we choose, we should confirm with our downstream customer (internal or external), that an improvement in this metric is of value to them. Otherwise, it's likely that we should be focusing on a different metric.

2. Choose Leading Metrics

The bottom-line metrics that we chose in step 1 are necessarily trailing metrics - they ultimately measure our performance when we deliver wafers to a downstream customer. The bottom-line metrics will tell us, eventually, whether our improvement efforts are yielding benefits. However, we prefer to also have metrics that will give us quick-turn feedback, so that we can measure our performance and adjust our methods in the short-term (in essence, we want to cut the cycle time of our cycle time improvement efforts). It is also much easier to quantify the benefit of a change if we can measure its impact in near-real-time, rather than waiting weeks or months for the effect to show up in a bottom-line metric.

For all of these reasons, we need leading metrics in addition to the bottom-line metrics. A leading metric is one that tells us weeks in advance what direction the bottom-line metric is likely to trend. Leading metrics for shipped lot cycle time include:

- Fab turns (operation moves / WIP).
- Fab dynamic x-factor (total WIP / WIP-in-tools).
- Dynamic days per mask layer (definitions vary, but generally any estimate based on recent activity, rather than shipped lot cycle time divided by the number of mask layers).

With a good set of leading metrics, we can tell within a few days if the changes we are making are having a measurable positive impact.

3. Decide: Do we focus on historical or immediate data?

Focusing on historical data is enticing, but in our experience it leads to an endless series of discussions about what went wrong, what has changed in the meantime, and whether or not the problem might happen again. Focusing on historical data also shifts the focus subtly from "what should we change?" to "how can we get the perfect data?". Our opinion is that it's more effective to identify and fix the problems that are happening right now, at least as a first pass.

4. Choose Red-Flag Metrics.

Whether we focus on historical or immediate data, we need a set of metrics that serve as red flags that cry out "here's a problem that needs to be fixed!". Red-flag metrics include:

- OEE for critical tools
- Worst wait time (longest queue time)
- Inactive lots (inventory age >= X)

If you look back at our sample leading metrics (fab turns, etc), you can see the added benefit that the red-flag metrics provide -- the red-flag metrics focus our attention on a particular tool, segment of the line, or set of lots. The plan is to fix the problems identified by the red-flag metrics, and then confirm that these changes show up as measurable improvements in the leading metrics.

5. Drive the Process via the Morning Production Meeting

If it hasn't happened already, the morning production meeting agenda should be revisited. The leading metrics and red-flag metrics need non-trivial and repeated exposure. Otherwise, inertia will prevail, and any cycle time improvement projects will languish in the middle of people's priority lists (not far enough down to be dropped, but not high enough up to be completed). This change may require dropping other topics from the morning meeting agenda. For ideas on what makes an effective morning meeting, please see our related newsletter article in Volume 8, Number 2.

6. Check for Common Root Causes of Cycle Time.

The red-flag metrics will point out problems that are likely leading to long cycle times. But the solutions to these problems may not be quick or cheap. In addition to the problems identified by the red-flag metrics, it is worthwhile to review a list of common root causes of cycle time. For each of these, we ask:

- Is it a problem for this fab?
- What, if anything, can be done quickly & cheaply?

Common root causes of cycle time include:

- Carts used for lot transfer
- Single-path tools and single path operations (the latter are often due to process restrictions)
- Operator preferences for particular tools over others
- Fab utilization (If many tools are near capacity, we expect a higher cycle time, and in this case we may not be able to cut cycle time greatly. Conversely, if only a few tools are near capacity, then we cannot blame the problem on utilization and we know to look elsewhere for solutions).
- Insufficient staffing for critical tools
- Batch tool loading policies
- Variability in tool uptime, and in scheduling of maintenance and engineering events
- Variability in lot releases into the fab
- Too many hand-carry hot lots, especially when tools are held idle for multiple steps ahead of the lots
- Misconceptions about cycle time (moving lots with big carts to save trips is more efficient; we need lots of WIP to keep all our tools busy; we can have many hot lots without impacting the rest of the line)

7. Tackle the Details

The problems highlighted in the prior steps are sometimes amenable to quick, one-step solutions. More frequently, however, a host of smaller changes are required to improve performance. Because they require coordination between various groups within and outside of the fab (including the IT and equipment engineering organizations), these changes will not be easy. If the focus on cycle time at the morning meeting is temporary, then these changes will likely never take place. But if the focus on cycle time is maintained, it is possible to effectively tackle details such as:

- Smoothing arrivals to critical tools. If smoothing is not possible, we need to manage the buffer in front of the critical tools.
- Identifying critical tools on a regular basis. If the mix is constantly changing (which it is for almost all fabs), then the critical tools will be changing as well.
- Watching for tool dedication creep. The natural trend is to have the number of single-path operations increase, not decrease, as new recipes are introduced into the fab.
- Making tool availability improvements, including those that focus on reducing the variability of availability.
- Managing masks - in general, we are looking for subtle non-tool single-path resource constraints. If masks are stored in mask sets, and the use of one mask from the set precludes the use of any other in the set, masks become a constraint that can cause cycle time.
- Getting the UPH data required for accurate OEE rate loss estimates.
- Managing cluster tools.

Summary and FabTime's Supporting Role

The checklist shown above is necessarily a starting point -- you would need to modify it for the unique circumstances in your fab. We think that a fab-specific checklist is a good way to codify the steps involved in cycle time improvement. At FabTime, we see our role as providing support for such improvements -- as an outsider we don't seek to drive the changes, but to provide the education (via our newsletter and cycle time classes) and software tools (reporting, dispatching, and capacity planning) for making cycle time improvements. In this way, you leverage our experience in cycle time, without having to develop classes and software internally.

We welcome your feedback on the details of the cycle time improvement checklist. If you don't think such a checklist is feasible, we would like to hear your opinion as well!

Subscriber List

Total number of subscribers: 2808, from 479 companies and universities. 21 consultants.

Top 20 subscribing companies:

- Maxim Integrated Products, Inc. (252)
- Intel Corporation (161)
- Micron Technology, Inc. (86)
- ATMEL (72)
- Analog Devices (68)
- Infineon Technologies (66)
- Freescale Semiconductor (65)
- X-FAB Inc. (62)
- International Rectifier (58)
- Texas Instruments (58)
- STMicroelectronics (57)
- Cypress Semiconductor (55)
- TECH Semiconductor Singapore (53)
- ON Semiconductor (51)
- Chartered Semiconductor Mfg (50)
- NXP Semiconductors (50)
- IBM (46)
- Spansion (38)
- Seagate Technology (33)
- BAE Systems (30)

Top 3 subscribing universities:

- Virginia Tech (11)
- Ben Gurion Univ. of the Negev (7)
- Nanyang Technological University (7)

New companies and universities this month:

- AZ Electronic Materials
- ErSol Solar Cells
- Marine Terminals Corporation
- Politecnico of Bari

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

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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).