Eliminating the Paper Runsheet; One Fab's Foray Into the Paperless World

Richard Helm, Travis Abshere, Lisa Huynh, Paul Brodie, Karen Zakaria
TriQuint Semiconductor,
2300 NE Brookwood Pkwy, Hillsboro, OR 97124
rhelm@tqs.com

Abstract

Paper travelers carry significant overhead in a dynamic Wafer Fab environment. This extended abstract describes how TriQuint Semiconductor converted their Oregon Wafer Fab to a paperless WIP management system using existing resources and minimizing the impact to production.

Introduction

The eventual move to paperless WIP management started simply enough with a conversation with an equipment engineer who was trying to determine a source of wafer chipping. Since wafers often break many steps after first being stressed he was tracking lot histories for multiple lots using paper runsheets. His method was to get copies of the runsheets and copy as many tools as he could to an Excel file. For operations that did not note the tool used on the runsheet he would refer to various tool specific logs to fill in the gaps. Even after spending hours to track down this information he could still only identify approximately 80% of the tools.

Tracking down wafer breaks and making other correlations between WIP movement and yield would be much simpler if equipment information were contained in a single database. Subsequent conversations led to the realization that improved lot tracking and WIP management also allowed for completely replacing the paper traveler with an electronic system. The "Mercury" project was initiated to provide more complete information to FAB operators, provide improved lot tracking, be more flexible in accommodating change, and log the tool ID at each operation.

The Project Vision

The Mercury project had multiple stakeholders, each with different priorities. The Operations group wanted a system that was flexible to process updates and provided clear instructions to operators. The MES group wanted a system that would work with existing resources and be compatible with the current infrastructure. Process Engineering wanted more detailed process information and a reduction in "hidden" process variation. Finally, management wanted minimal impact on factory output during the transition along with a payout in increased yield and reduced misprocessing.

To address the requirements of all groups, representatives from each were included in the core Mercury team. In addition the Director of Fab Operations and the Director of Process Engineering were co-sponsors and active participants.

The decision was made early in the project to go completely paperless. This included standard WIP transactions, reworks, engineering lots with special processing, and qual wafers. Although this added greatly to the complexity of the task it greatly improved visibility of the wafers in the system at all times. This in turn made it much easier for operations to plan and track equipment usage.

For our MES system TriQuint uses Workstream on an Informix platform. There are multiple modules available in Workstream to fully integrate WIP processing and dispatch (RBD) with equipment (RTC). While there are many benefits to be gained from implementing the whole package, the Mercury project focused only on the WIP tracking. Implementation of RTC and RBD are future planned projects that will add more safeguards to prevent the mis-process of lots.

The goal for the Mercury team was to develop a WIP tracking system within Workstream that when combined with standardized work methods would provide the operator with all of the information required to correctly process wafers at every operation, collect information on operator and tool and to implement as many safeguards as the system will allow to prevent mis-processing of wafers.

MES Considerations

Workstream operations are assigned a 4-digit number from 0001 to 9999. Number ranges were set aside for each process area (e.g. Wafer Fab, Die Sort, Fab Finish, etc.) and for repetitive process tasks such as reworks, engineering splits, qualifications, and carrier clean processes. The concept of a separate operation for each production task or Fab tool type is the foundation of the system. Each operation can then be reused in any number of routes, and routes can be assigned to any number of products, to create product flows.

A Product in Workstream is assigned one or a series of routes that define the process steps for that product. At the most basic level a Route is composed of one or more Operations each with a move-in (MVIN) and a move-out (MVOU). In comparison, the runsheet was a printed list of the Workstream operations with additional processing information detailed for each step. A single Workstream operation on our paper system might cover as many eight different tool operations that could occur at different locations in the Wafer Fab. This made identifying the physical location of a lot difficult.

In order to eliminate the paper runsheet it was necessary to capture the information on the runsheet electronically. The functionality in Workstream that allowed this information to be captured and displayed is a script. A script is code that controls what screens will be displayed in an operation and what information will appear on each screen, see Figure 1. It is these script screens that are used to provide information to the Fab operators concerning: allowed tools, the recipe to use, the governing specification and any special instructions such as special cassettes or notch alignment.

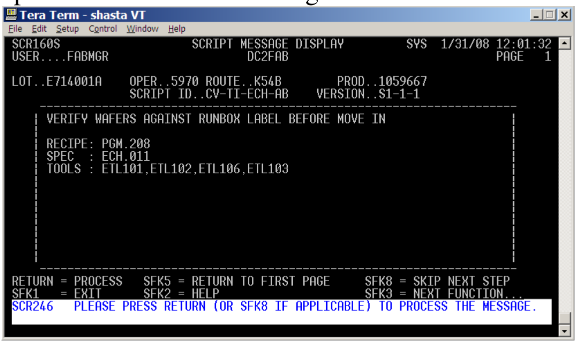

Fig 1. Script Instructions

Standardized naming conventions were used wherever possible for operation descriptions and groupings, script IDs, and entities (tools). This provided a means for dispatching all lots by Fab bay and tool type, as well as reporting of starts, moves, scraps, reworks, outs by area, etc.

One feature of Workstream scripts is the script must be compiled and "frozen" before it can be used. Once frozen a script cannot be modified without revision control. The Mercury team took advantage of this feature and forced the script naming convention to incorporate a means to track revisions. An external Recipe Database and associated procedures were created to manage all changes to the scripts.

Reworks were also included, through use of standard Workstream split, rework and merge processing. Prior to this, reworks were done offline, making it difficult to determine the true status and location of a lot, even with the paper traveler.

Standard Workstream functionality and configuration options were used whenever possible, but several customizations were required. The major customization was a change to the Move In and Move Out screens to include the Employee ID and Tool ID. These two items, along with splitting the steps into individual tool or process steps, fulfilled the need for traceability that originally spurred the project. Bar-coded lot boxes, employee badges, and Fab tools allowed point-of-use entry and validation into the system. A mix of computer workstations and wireless PDAs was chosen for logging the Workstream transactions. Another customization was a lot status screen that incorporated site-specific data, such as lot attributes and script instructions.

The end result was a consistent process and work methods for all lots (production, engineering, qualification, carrier), along with visibility and traceability of all lots.

Several web-based tools were created to give engineering and production visibility of the product, route, operation, and script setup data, outside of the Workstream application.

Implementation Methods

A new Workstream facility was created to house the new operations, routes and scripts. This new facility operated in parallel with the existing facility and as each new route was built and qualified, new lots were processed there while WIP in the old facility was flushed out.

To accommodate the increase in transactional load caused by the additional Workstream operations a second application server was added. To provide increased security for transaction history, synchronous database replication was employed. This ensures an up to date copy of all data in case of hardware or system failure. This is a critical added functionality since there is no longer a paper record to serve as backup.

As new routes were created, a few closely monitored production lots were sent through the line to work out any problems in the process itself, work methods, tool interfaces, cross-system interactions, etc. Refinements were made, and all new lot starts for that process were then done on the new system. To minimize confusion, lots designated to run on the new paperless system had several identifying characteristics. Lots started in the new Workstream facility had lot numbers beginning with an E where lots on the old system started with an A. In addition lot boxes were color-coded to indicate if they were "paperless".

New Route Creation

Critical increases in functionality that the new system provides to both operations and engineering were achieved by breaking our large grouped process steps into individual small steps with each including only a single move through a tool. This required taking each existing route and breaking every sub-step out into a brand new step, a typical Wafer Fab route from lot start to wafer complete expanded from about 70 Workstream operations to about 350 Workstream operations. Since TriQuint has a varied product line as well as a foundry business, there were many routes that needed to be converted, making this the most time consuming task in the project. While every manufacturing facility is unique many of the concepts used in Mercury have a general application.

First, only a couple of routes were converted (i.e. substeps broken out into individual steps). The route conversion method was produced based on this initial work. The information from the paper traveler was converted into an Excel file with one row for each new operation and each row contained columns where all of the information required to define an Operation and Script in Workstream could be entered. Also, many of the substeps (now individual operations) created were usable in the many routes to follow. After the first two routes, every new route creation started by identifying as many steps that could be reused as possible. A step naming convention (10 characters) was created that provided tool location, associated mask layer, tool family, and 3 characters to allow for a unique step name. One of the last 3 characters was a letter that could be assigned to a new route. That way, multiple routes could be produced simultaneously without fear of producing identical step names.

Every new route began as a listing of operation names with no process information. Once this list was made, it was sent out to process engineering to fill in all relevant information on allowed tools, recipe, special instructions, etc… In most cases each new script was a modification to an existing "template" script and the spreadsheet included a column to list the "template".

The operation number in Workstream is the unique identifier for the operation so all new operations for a family of routes went through a single person to have operation numbers assigned in order to prevent duplication. Finally, once a new route was created, it was compared step by step with the original route to make sure no steps were inadvertently added or omitted. In all, 325 unique routes were created, although some only have a few subtle differences.

Training and Implementation

An official kick-off meeting was presented to all Manufacturing shifts. To show complete support of the conversion, Management, including the Vice President of Operations was present. Post-kickoff, online-training materials were made available and an e-mail distribution list, comprised of the team members, was used as a forum for Operations to provide feedback. Online screen-shots of each transaction became very useful, as personnel had to broaden their MES vocabulary, which in most cases were limited to MVIN or MVOU. Trainers were given labeled "dummy" run boxes for their trainees to practice transactions on a test system. The basic core of the training was learning to decipher the new short description, since this provided the location and destination of the lot on hand.

Each Workstream operation has three fields called Operation Groups that can be user defined. For Mercury Operation Group 1 is the general work area, such as FAB or Diesort. Operation Group 3 is a specific Bay in the general work area such as Photo or Test and Operation Group 2 is the Bay workcenter such as Coat or Develop in Photo.

To organize where lots would be staged, each WIP rack shelf was labeled with the Operation Group 2 and unique short descriptions. A dispatch report was created to match this grouping.

Considerations for the flow of material to and from work-centers were imperative. A transaction needed to be as quick as verifying the correct recipe from an electronic specification and signing an operation off on a paper traveler. Approximately 80 PCs were deployed throughout the factory based on the concept of every tool having a terminal readily available for MES transactions and recipe and tool verifications. For areas where there was a lack of space, a handheld PDA or a laptop was installed. A barcode of each tool I.D. was placed by the tool or terminal. A card with a list of short-key transactions was attached to each PDA. Similarly, laminated sheets with the basic barcode requirements were provided at every desktop and laptop. These sheets also doubled as mouse-pads. Every operator and technician was issued a 2.5"X5" badge with a barcode of the individual's I.D. Badges also served as a reference for other useful MES transactions. With tools and references readily available, lot-tracking became more efficient.

Difficulties arose when off-system processing, once a standard practice, was prohibited. The Operations group was forced to hold orders when scripts had errors or the process had simply not yet been converted to the new system (e.g., rework routes). Old habits and the need to meet production metrics bred a tendency to write a disposition and "create" the route on a sticky-note. This method bodes for a misprocess or a non-traceable line variance. As much as possible, the team addressed these issues by working closely with process engineers to create the appropriate routes and scripts. For non-standard cases in which lot-tracking could not be done in MES, use of the existing electronic run-event-log replaced clean-room sticky-notes (eventually banned from the factory).

With every operation on system, the benefits of converting to a paperless method were evident in managing the WIP. At first glance of a dispatch report prior to the conversion, the current operation of an order was usually only a clue of its exact location. Supervisors often needed to physically locate the order to determine its position in the line. Moreover, the source of an order's queue time was not always apparent, so it became somewhat of an intuitive guess as to what to tackle when attempting to address cycle time issues.

After the conversion the dispatch report described the exact location of every lot in the line down to the shelf where the lot was staged. With tool level resolution of MVIN and MVOU times specific tools with long queue times were easily identified.

Recipe Database

Since all process information would be contained in the script embedded in the MES tracking system, all process changes would need to be clearly communicated to the MES group so that the script could be updated accordingly. In addition, the changes need to be reviewed and approved before the script is updated. It was obvious that there was a need to develop a system that would allow process engineers to submit the process changes for approval and implementation. The Recipe Management Database was developed to fulfill this critical requirement plus to provide many other benefits such as searching and reporting process information and tracking change history.

The database consists of tables containing process information for all operation steps and a user interface that allows different groups to interact with the database such as requesting, canceling, approving and disapproving changes as well as searching for specific information. The process information includes step name, step description, set-up instruction, reference specification number, an allowed tool list and the recipe name for all operation steps. There is also a daily auto-generated email notifying the MES group for any discrepancies in the database versus the MES script. This is to ensure that the information in the database is identical to that in the MES script at all times.

New change requests have to be approved before the script can be updated and activated and the database has an auto email function that notifies approvers when there is a change. The search feature is essential to query for common steps per recipe or tool or operation type. This helps to identify the affected operation steps when a process change is required. It is also useful to be able to search for history of a specific operation step, when and why the change occurred and who initiated the change.

The creation of the Recipe Management Database enabled the additional benefits listed below.

- Eliminating all recipe cross reference tables from many separate process specifications
- Ability to specify the exact date and time when the process change should take place meaning when the script should be activated
- Ability to track all process changes and pinpoint the time stamps of the changes. This could quickly help to identify the root cause of problem if there is a yield shift on a certain process flow or lot.
- Automated notification email capability to communicate the status of the change request to the appropriate party

By embedding the recipe information in the version controlled Workstream script and controlling and tracking recipe changes through the time-stamped recipe database it is now possible to track process changes to the lot level.

Results

The transfer of all wafer production starts to the new Workstream facility was completed on schedule in Q1 of 2007. Completing all of the production routes did not mean the end of the project, rework and qualification routes needed to be created, procedures needed to be refined and documentation updated. These activities continued into Q3 of 2007.

The goals of the major stakeholders were met; the new paperless system is flexible to change with revision control of scripts providing lot level traceability of process updates. The new system is an extension of the already existing Workstream application with more robust hardware and improved data security. The FAB operators are provided with lot specific processing instructions including the qualified process tools and correct recipe. The processing information is controlled and verified daily by an independent revision controlled database that also provides a standard method for engineering to request and approve process adjustments.

Breaking down the processing routes to single tool operations gave process engineering increased visibility into the process and allowed more sophisticated data analysis of process variation. In one example having the exact move in and move out times through a wet etch allowed analysis of a critical parametric parameter to bath life. This analysis revealed the variation in the parametric data that was leading to wafer scraps came from wafers that were processed during the second half of the bath life. Doubling the frequency of chemical changes significantly reduced a major cause of scrap.

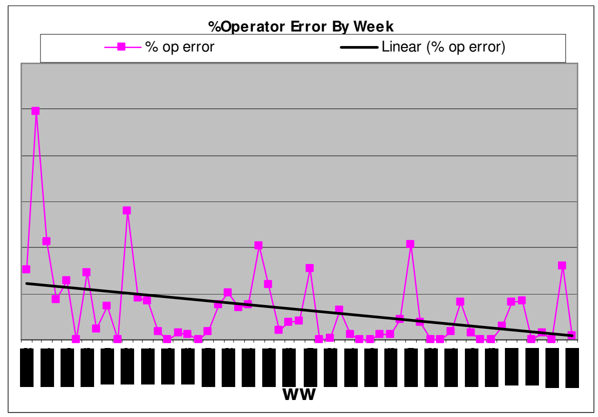

Fig 2. Decrease in Operator Error

One goal of operations was to reduce operator error and the chart in Figure 2 shows the decrease in operator error from the beginning of 2007 to present.

Summary

Management had requested a system with minimal impact on factory output during the transition and providing increased yield with lower operator error. The improvement in operator error has already been shown and the increased visibility into the process has allowed process engineering to make new discoveries that have reduced scrap.

Not only was the impact to factory output minimized during the transition but factory output was ramping up all through the transition. By the end of 2007 with all of the pieces in place, factory output was up, yield was up, cycle time was down and operator error was at record low levels.

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