The Development of a Custom, Paperless Shop Floor Control System for Efficient Manufacturing

Marc Sherwin, Jason Moore, Jeff Hladek, Mike Roberts
M/A-COM Fab-II
1110 B Bayfield Drive
Colorado Springs, CO 80906
Phone: 719-527-5802, Email: sherwinm@tycoelectronics.com

ABSTRACT

To gain manufacturing efficiencies and reduce manual overhead in our production control cycle, M/A-COM Fab II has developed a custom shop floor control system to manage wafer production. Derived and extended from our previously developed post-fab WIP system, the new fab system realizes significant labor and paper savings. The primary goal of this work was to integrate inefficient, disparate systems that controlled documents, lot recipes, lot WIP, discrepancy reporting and equipment maintenance while developing a low maintenance MES system.

Major improvements have included automatic presentation of temporary or permanent document changes to the operators by events triggered by lot movement in the production system, negating the need to manually distribute document change notices throughout the facility. The equipment PM system allows tracking of numerous PM events for each piece of equipment by either time or wafer count, which allows for better matching between wafer volume demands and routine maintenance.

Given past experience with other systems, strong focus was put on developing a system with an efficient user interface and minimal system maintenance requirements. We are experiencing significant time savings through out the fab; as an example, many production control jobs that used to take 30 minutes now take less than 1 minute.

PAST HISTORY

Before FabII was purchased by M/A-COM, the fab(as part of Cray) was controlled by a UNIX-based system called CAMEO. CAMEO was based on Oracle running on a Unix server with dumb terminals located throughout the fab. For the last 3 years, FabII has been running on text based PROMIS.

PROMIS AND CAMEO were good WIP tracking systems, but were not great database systems. Data collection, retrieval and correlation were inferior and required custom bolt-on solutions. Both of these systems required paper travelers, off-line data collection and had very high barriers to integration with other systems. Both systems were also text based and required a great deal of key-stroking. However, many years of experience with both CAMEO and PROMIS have helped to define our needs and better educate us about what should be possible in a WIP system.

GOALS

Before beginning down the path of developing our own WIP system we laid out a number of goals for this project. The primary goals were: A) Go paperless in order to reduce the high maintenance costs of 25+ page lot travelers; B) Integrated in-line data collection (film thickness, run numbers, etc); C) On-line ECN and ISO documentation to provide instant updates and eliminate paper distribution manpower; D) Integrate previously disconnected systems such as equipment maintenance functions and PM schedules; Inventory/WIP reporting; and Product Discrepancy (PDN) reporting; E) Build a graphical, intuitive, easy-to-use system that has a short learning curve; and F) Design a system that requires minimal database and code maintenance.

Although we stood to gain many benefits by developing our own system, we were careful to avoid many of the pitfalls associated with a custom system. We used with commercially standard software and the leading database software. As we are not immune to personnel attrition, the system is low maintenance and the code is accessible and fully documented.

SYSTEM DEVELOPMENT

The WIP system has been developed to run in a standard client-server architecture. The primary database for this system is Oracle 8.0.5 running on a Windows NT server. The server is dedicated to running the database and has redundant hardware including dual processors, RAID 5 Hard-Disk storage and dual power supplies. The client machines are standard WINTEL machines running Windows95,NT or 2000.

The client software was written in Microsoft Visual Basic 6. A number of Active-X plug-ins were purchased to provide additional functionality for charting, reporting and document viewing. These plug-ins are relatively cheap (~$500) and often save weeks of development time. Database operations were performed in Oracle PL/SQL where possible to reduce network traffic and improve overall performance. The Oracle database has been specifically designed to minimize the need for any routine table maintenance and should only require standard backups. In order to reduce database search times for routine transactional queries, tables were developed that hold information only for the lots that

are currently being processed. Historical information for previous lots are stored in separate tables. This will keep the active tables small and the routine processing transactions fast.

The hardware and software cost for the entire system rollout was less than $75K which included the server, 33 Compaq iPAQs and network cabling and routers. We have chosen to place enough PCs in our facility so that an operator does not have to walk more than three steps from any terminal to their work station. Some of the iPAQs were equipped with flat panel screens to save precious room within the fab. The development team consisted of three people (working on other projects as well), for a total time of less than 12 man-months. We currently have one full time programmer working on the project to extend the system and add new capabilities. The system can be expanded to use bar-coding for select functions.

SYSTEM FEATURES

The highly integrated nature of this system means that although the heart of the system revolves around moving the lots through the process, this represents only a portion of the total features. The fundamental design approach of the complete system was to develop modules that interact with each other through the database or at the graphic user interface. As an example, equipment PM events and lot tracking are completely independent except for two cases. First, when a lot is tracked through a piece of equipment, the wafer count is incremented for that equipment, which may be used to trigger a PM event. Second, if a PM event is missed, the equipment will be placed in the down state, making it unavailable for lot tracking. These two events are independent except for the interaction through the database tables. This approach has made it easier to develop each module with mostly independent rules.

Lot Trackin/Trackout - All lot transactions are accomplished from the WIP page shown in Figure One. Point and click processing is used to track the lot in and out of a process step. To save time, we do NOT ask the operator at each step if there is a comment or how many wafers are in the lot. The only way to remove wafers from a lot is through PDNs (described below) and comments can be optionally added to a lot at any step.

Operation/Spec Display - Whenever a lot is selected on the WIP page, the text for that operation is displayed at the bottom of the page. The operation text can be up to 2000 characters and can include variables. These variables (such as $BAKE_TIME) can be defined at the fab, route, process ID, mask or lot level in increasing priority order. In addition, up to four documents may be linked and referenced to each operation. Double clicking on the spec list will launch a document viewer that will pull up a MSWord document from a read only network directory.

Conditional Flow - In addition to conventional operations, the procedures may include IF/THEN/ELSE and GOTO statements. These statements can use variables, lot information (route, location, etc) or collected data to make operational decisions. An example is presented in Figure Two. The last operation in a lot's route will be used to move the wafers into an inventory state, making the wafers available for disposition and/or shipping.

Data Collection - The data collection process is defined by "Data Templates". These templates may be reused by multiple operations as the data is stored by lot/area/date and operation. If a template is associated with an operation then the data collection page will automatically be displayed at trackout. The data can be wafer or lot based and the lot based data may be calculated on the wafer data. As an example, this makes it possible to collect sheet resistance for each wafer in a lot and then *automatically* calculate the lot mean and % standard deviation. Each item in a data collection can have defined specs and can be classified as optional and/or critical (causes a PDN event - see below). Users with sufficient clearance (supervisors) can bypass required data collections in the event of down test equipment. Built in SPC charting can be used to present graphs to the operators at run time.

TECOs/DECOs & ECOs - Temporary and Developmental Engineering Change Notices are automatically checked *before* a lot is tracked into every operation. The operator must acknowledge each notice and the event is recorded in the lot history. If an operator states that the notice is not followed (perhaps it is ambiguous or non-applicable), the originator of the change notice is notified by email. The change notices can be linked to operations, ISO specs or equipment used. When an operation is displayed, the ISO specs (up to 4) associated with that operation are checked for any pending changes. If a spec has been revised, each operator is notified and forced to acknowledge the change the first two times they see the spec following the rev and the acknowledgment is stored in a history file. In addition to formal change notices, users have the ability to generate future notes and future holds that will be checked at each trackin and can be used to feed forward more informal information

Process Discrepancy Notices(PDNs) - Any time something unusual happens to a lot it should be recorded by a PDN. The PDN system can be automatically triggered when collected data is out of spec or critical timing limits are missed. The PDN is the only mechanism to scrap wafers out of a lot and provides detailed information about which wafers are affected, their disposition, the cause of the event and who or what is responsible.

Equipment PMs - Multiple Preventative Maintenance events can be scheduled for each piece of equipment and can be

specific to the equipment function. This would enable a three chamber machine to have different clean schedules for each chamber. The PM events can recur on a time basis or a wafer count basis. In addition, at a user definable notification time, the maintenance tech will be alerted, by email, in advance of the drop-dead time. This allows sufficient time to order supplies or prepare alternate parts. If a PM is missed, the maintenance manager is notified by email. Each PM event can have an associated checklist that allows the technician to check off each item and perform effective project transfer at shift change. A simple MSWord document with more complete details can also be linked to each PM event.

Security - Almost every single function that can be performed on lots or equipment is controlled by variable access levels. As an example, junior operators can be given the ability to track lots in and out of operations, but can be restricted from performing lot splits/merges or other advanced functions. The ability to edit the controlling information (routes, procedures, variables, etc) is also controlled with security. Everyone has the ability to read/view data and generate reports.

Reporting- When system development began, one of the primary goals was the development of good, useful reports. Prior to this system, our production, production control and QA managers were all tracking the wafer yield slightly differently and often had numbers that disagreed by a wafer here or there. By developing a fully integrated system we are intending to do away with individual spreadsheet reporting and use more standard database queries that can be used by the different departments. Reports are user configurable and can be generated from many of the modules described above. Multi-page viewing, zooming and printing are standard features. In addition, we have made every effort to make the data easy to export for analysis off-line with 3rd party tools.

Material Tracability - As our intention is to use this system without paper travelers, *all* information about a lot's processing must be accurately stored and easily retrieved. We have taken great pains to ensure that every event that a lot encounters is accurately reported. As an example, although variables used during operation display can be easily changed, the state used to display the operation text to an operator is recorded in the lot history so it can be recovered at a later date.

Data Integration - On an hourly basis, the FabII system generates a WIP report that is then imported into the corporate SAP system for integration with the financial departments. Additionally, we are working hard to fully integrate our lot moves, in-line data, PCM data and packaged parts data into one database. The goal of this work is the ability to query all the information about a wafer with one statement and determine critical correlations that impact final test yield. In support of the Oracle database, we have a standalone PC performing routing repeating functions such as SAP file generation, email generation, TECO expiration, etc.

Multi-Fab Applicability - One of the keys in developing a strong robust system was not to program in too many Fab II specific needs. Although we wanted a system that would address all of our needs, developing the system to work in a generic fab has produced a more general tool that is more adaptable to our changing needs. This has also enabled us to produce a tool that can be easily transported to other fabs within M/A-COM if desired.

PERFORMANCE

The system has been controlling our production since October 2000. After a short period of fixing glitches, the routine code/database maintenance of the system is no more than a couple of hours a week. We are however, constantly working to add new features. The integration of lot tracking, equipment information, in-line data, etc has enabled the removal of redundant data entry: Lot Paper traveler, equipment log book, manual SPC chart. The current system has reduced this to a single, efficient operation.

We are still not completely paperless within the fab, but the elimination of paper lot travelers and many log books should enabled saving approximately 100,000 sheets of clean room paper a year, in addition to the manpower needed to print/maintain and file the travelers. Perhaps the greatest time savings are being realized in production control and document control. The old method of printing a traveler, checking any temporary notices, issuing the traveler, etc. used to take at least 30 minutes. With the new system, launching a production lot takes 30 seconds and any temporary notices are automatically included at the appropriate operation. Document control no longer needs to distribute specs to numerous paper binders, as specs are accessed online. When temporary engineering changes are made, the computer system takes care of tracking down the affected lots, negating the need to physically find the lot and annotate the traveler.

It has been our opinion that good fab control software is just as critical as any multi-million dollar fab tool. We have taken the approach of investing limited money and a few people and have found that we have developed an excellent tool for control of almost every aspect of a semiconductor fab. Although the same end result could be accomplished with commercial software, it is our belief that we have a tool that is just as good, cheaper, and better suited to our individual fab's needs.

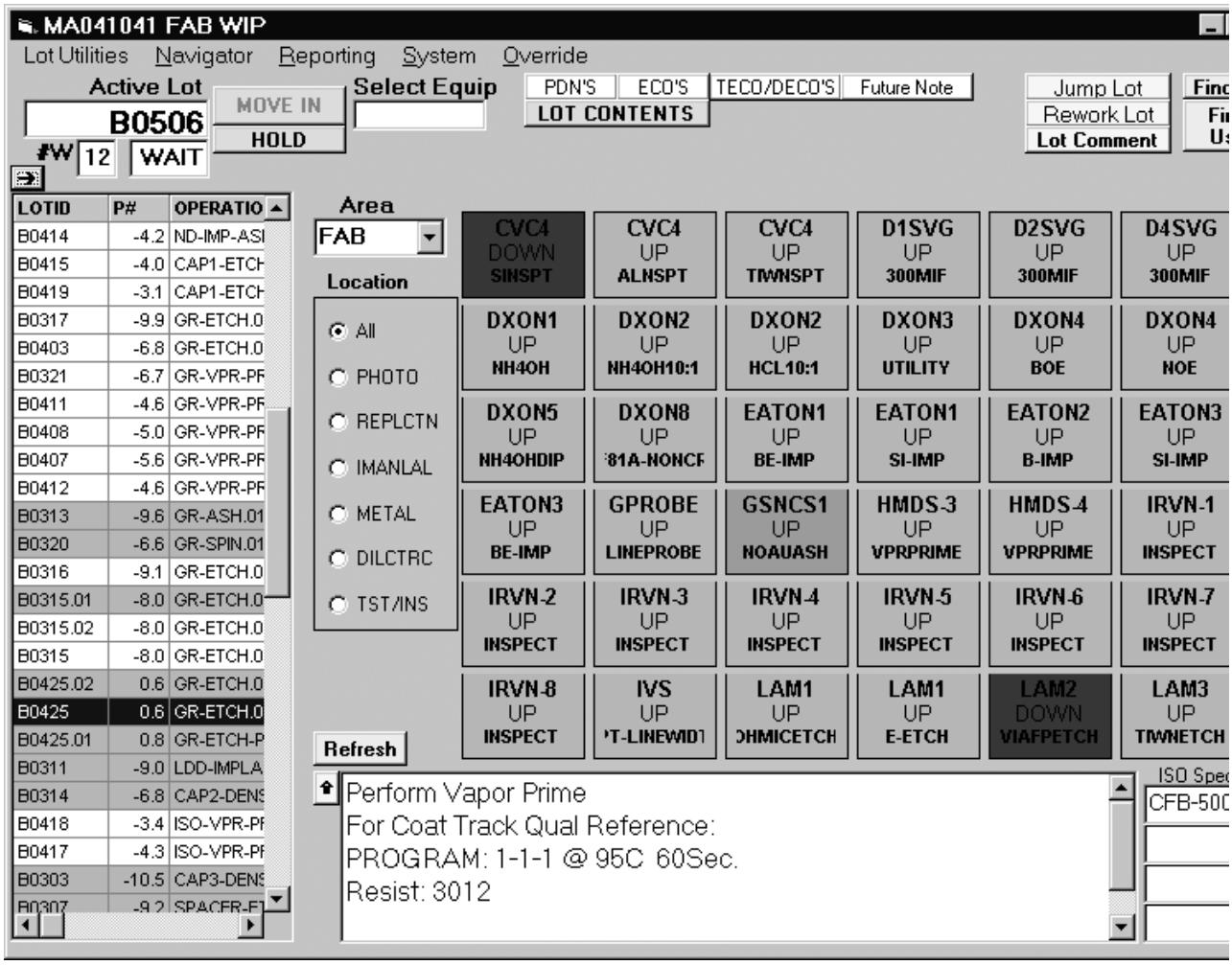

Figure One: This is the graphical WIP page where the operators can move lots, adjust equipment and perform all normal functions from this single page. The lots are color coded for waiting, running and held. The equipment is also color coded for Up, Down, PM, Qual.

Operation Display Text	Explanation
Implant Si29: $Dose at $Energy kV	The two variables will be replaced at runtime
IF $OHMIC_THICK > 2500 THEN	The variable $OHMIC_THICK can be linked to an earlier data collection and will be used to determine which operations to perform.
Anneal Wafers using Program 7	Operation to be performed in a TRUE case
ELSE	
Anneal Wafers using Program 5	Operation to be performed in a FALSE case
END IF	
MOVEINTO INV-THICK	Completes the lot and moves any remaining wafers into INV-THICK location.

Figure Two: Examples of operations that can be used during lot processing. The conditional flow operations are executed, but not displayed to the operator.