# Factory Automation beyond Recipe Selection

N. Thakkar, D. Beasley, A. Lopez, R. Caguioa, G. Hafer

Skyworks Solutions, Newbury Park, CA 91320
nirav.thakkar@skyworksinc.com  +1 (805) 480-4325

**Abstract**

**Factory Automation in compound semiconductor manufacturing is done primarily to prevent mis-processing of wafers due to wrong recipe selection. Automated recipe selection through host application is the most common approach to achieve this. A host application is simply a software application running on a computer connected to the tool computer and communicating using SECS/GEM. However, there are many other ways factory automation can be applied to save engineering time, precious consumables like metals and chemicals, aid process enhancements, troubleshoot equipment or process problems, improve throughput, etc. This paper describes how Skyworks Newbury Park has achieved these through various home grown software applications.**

INTRODUCTION

With a small team of software developers, we have developed host applications for the tools that are SECS/GEM capable and different applications to prevent mis-processing for the ones that are not. By extending our host application to the next level, in some cases by simply using the data collected from the tool in unconventional ways and by combining equipment data with MES data, we have been able to improve yield and throughput, reduce WIP and cycle time, identify and fix problems faster and provide required data to various group at their fingertips for decision making.

RECIPE MANAGEMENT

*Version Control*

Making sure that the latest revision of production release recipes are running on all tools of the same type could take up a lot of engineering time. Even then, there is a possibility of someone accidentally modifying production released recipes on the tool. On non-networked tools, backing up production recipes regularly could also be challenging. We have solved all these problems by developing a Recipe Management module and adding it to our host application. Anytime a production recipe is released to production, it is first uploaded to a central repository, which exists in the data center and is backed up regularly. During the upload, Recipe Manager updates the version number and creation/modification timestamp in a database. During a production run, the latest version of a production released recipe for the lot being run is always downloaded from the repository before starting the lot.

This approach also offers us a history of recipe modification with a timestamp and the person modifying the recipe. By implementing this, we have achieved zero mis-processing due to wrong recipe.

*Runtime Parameter Overriding*

Typically, you have as many recipes as permutation of process parameters. In some cases this is quite a big number. On our steppers, we had as many as a few thousand recipes due to many parameters like focus, exposure, x & y offsets, etc. More recipes mean more time to manage them and higher the probability of making an error. We use runtime parameter overriding for our steppers, where we create vanilla recipes, and then override these parameters at runtime through host application. These parameters exist in a database and we have developed a web interface for process engineering to easily create and modify them. This approach has reduced the number of recipes on our steppers by 16 fold.

*Recipe Modification Approval Process*

Historically, we had one system to approve and document recipe modifications while another to change recipe parameters - a web application as explained above. This created two problems: Making sure both systems showed the exact same change of parameters, i.e. there were no typos, and making sure that the actual parameter modification happened soon after the final approval. With a large group of process engineers for the same toolset, there is also a concurrency problem, where there is a risk of two or more engineers modifying the same recipe. We have created a web based recipe modification and approval system, where engineers can create and change recipe parameters and submit for approval. E-mail notifications of creation/modification and approval/rejection are sent to designated people. When the final approval is given, the change(s) becomes active and the next lot picks the new recipe. We also solved the concurrency problem by not allowing any other parameter change while one is pending for the same recipe. In addition, we have integrated our tool dedication plan in this system, so that changing the tool dedication goes through the same approval system.

ALARM MANAGEMENT

Many tool alarms require engineering action(s) such as wafer inspection or equipment maintenance. With tens of different kinds of alarms, it is difficult for technicians to remember which alarm requires what action(s). Even then, there is a possibility of someone forgetting or taking too long to act on

it. We have developed a web based Alarm Management System which enables engineers to define what actions should be taken in response to specific tool alarms. Actions could be any combination of: Putting tool down for Equipment or Process Engineering in MES, Putting lot on hold, E-mail/Page someone, or simply display a custom message on the host screen. An example is shown in Fig. I. Any time an alarm is received from the tool, the host application takes the defined action. By implementing this system, we have not only made yield improvements, but also reduced the MTTR (mean time to respond) by 50%.



FIG. I: CONFIGURING ACTIONS FOR A TOOL ALARM

ALARM PARETO

Based on the alarms received from the tools, we have provided a web based alarm pareto report (Fig. II) for equipment and process troubleshooting and enhancements. Drilling through the report gives occurrence details, including recipe and wafer information for a user-specified time period.
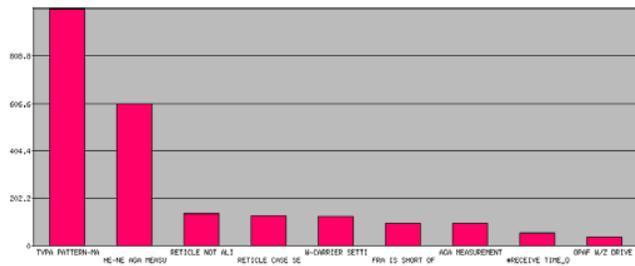


FIG. II: ALARM PARETO REPORT

MEASUREMENT FEEDBACK INTO PROCESS

Many of the process steps are followed by measurement steps. When the measurements are out of spec, there is a possibility that there is something wrong with the process tool or process itself. Through control charts and parameter passing, we identify which tool processed the out-of-control lot and put that equipment down for either process or equipment engineering in MES. We have done this on our grinders and thickness measurement tools. If the metrology tool finds the wafer to be too thin then it puts the grinder that ground the wafer down for process engineering to look at. This prevents further wafer scraps.

On a different toolset, Alignment offset measurement tool, we can use the measurement data to adjust the stepper offsets automatically by applying an algorithm defined by process engineers to the raw or aggregated measurements periodically. To keep process engineering involved, the adjustment of the offsets is considered "Recipe Modification" and follows the approval process as explained above.

PRECIOUS METALS AND CHEMICALS USAGE

Keeping track of precious metal and chemical usage by tool, recipe, shift, etc. can lead to important information such as a tool problem, side effect of a process enhancement, etc. The biggest problem with any consumables tracking system is to get 100% compliance by enforcing everyone to use the system. We have solved this problem by integrating this with our host application, such that before starting a run on a metal tool, the host application requires the users to enter pre and post pocket weights, which guarantees 100% compliance. Based on these inputs we have created many useful web reports such as the ones shown in fig III. Drill-through on the summary usage report gives usage by tool (fig. IV) and 2nd level drill-trough shows details for each run. Similar reports are created for chemical usage as well. This also helps our sourcing department to more accurately forecast precious metal and chemical use.
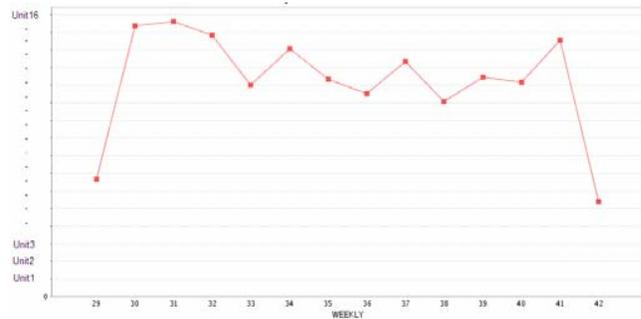


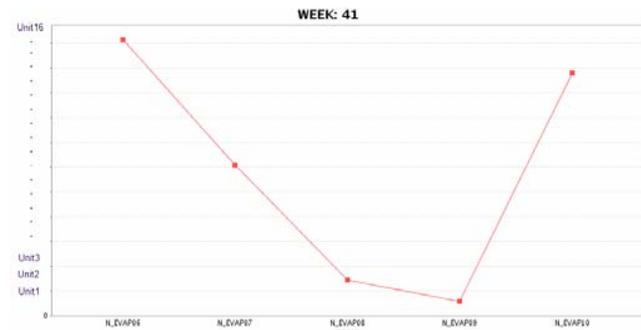FIG. III: PRECIOUS METALS USAGE SUMMARY



FIG. IV: PRECIOUS METALS USAGE BY TOOL (DRILL-THROUGH)

FAULT DETECTION

Our fault detection system uses the metal usage data collected from the metal tools and calculates how much metal is consumed by each tool for a single run of the same recipe.

Any spike in consumption on a single tool could signal a tool problem. Fig. V shows such a report.
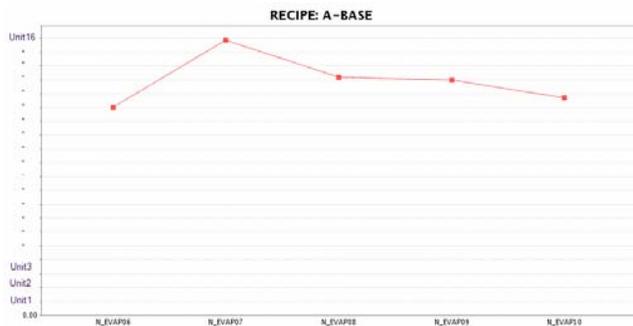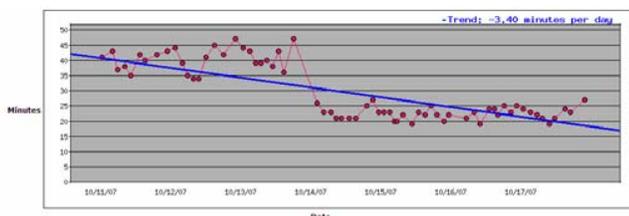

FIG. V: FAULT DETECTION SYSTEM

We developed a different fault detection system for our plasma-therm tools, which are not SECS/GEM capable. We networked the computers of the tools and developed a data collection application. This application detects creation of a new data log file, archives it to a network location and parses the data to load into our engineering database. Along with parsing data points, this application also assigns the lot, process and step information to the data points and creates a summarized table of aggregated values, which enables troubleshooting to be faster and easier. Engineers can use Excel, Jump or any other data analysis application to retrieve the data and analyze it. This application can also be connected to the Alarm Management system, which can put the tool down or hold lot in MES if a certain parameter is out of spec.

PROCESS IMPROVEMENTS
*Tracking Pump-down times*


FIG. VI: TRACKING PUMP-DOWN TIMES

By getting traces of pressure samples from metal tools, we calculate pump down time for each run. We have provided web based reports such as the one shown in Fig VI, to track pump-down times over time. Drill-through capability provides time-series pressure data. This allows the process engineer to monitor tool performance, and quickly alert the equipment engineer if there is a tool problem.

*Melt Aging*
The same interface to enter metal additions in the host application captures making new melts as well. Combining this information with the run count gives melt aging both in terms of time and number of runs. This report helps process engi-

neering to form guidelines on changing melts and also to verify if certain process improvements yield desired results.

EFFICIENT PM MONITORING
For our metal tools, we have provided a web based real-time Thickness Report, which accumulates metal thickness for every run based on which layer uses how much of each melt. Equipment engineering uses this report to schedule minor and major PMs. This is a more effective PM monitoring method than the time based one.

YIELD IMPROVEMENT
We have some tools that are not SECS/GEM complaint and can't be upgraded. To prevent mis-processing on such tools, we use PDA based barcode scanners such as the one shown in Fig VII to host our home grown application. For example, on manual wet benches, we have stuck barcode labels to the outside surface of each bath. Before dipping a lot, the operator scans his/her badge for username and password. Then he/she scans the lot box, which the application uses to make sure that the lot is at the right step and not on hold. Next the operator scans the barcode of the bath to be used, which verifies that the tool is available for production and the recipe required by the lot is allowed to run on that tool. Once this is done, the application checks the mapping table to make sure that the scanned bath is the right one for the scanned lot. If so, the lot is tracked into MES and a green light is given to the operator. If not, an appropriate message is displayed with a red light indicator to signal that the bath is not right. The operator can then scan another bath and is allowed to dip only after he/she receives a go ahead from this application. The entire process of scanning and making sure that the right bath is used takes less than 10 seconds. After implementing this system, we have had zero mis-processing on our manual benches due to wrong dip.


FIG. VII: YIELD IMPROVEMENT ON MANUAL BENCHES

PLD SYSTEM
We have developed a web based Problem Lot Disposition System, which makes sure that problem lots are handled appropriately and not shipped to the customer unless it has passed through the proper procedure. When a lot disposition (or PLD) is created, problem category, type and keyword is

specified along with the assignee (Fig VIII). As soon as the PLD is created, the lot is assigned a designated location in the MES, from which the lots can't be shipped and hence won't show up as shippable WIP in any reports. E-mail notifications are sent to appropriate teams about the creation and modifications to the PLD. Other authorized personnel can modify, re-assign, add attachments or submit PLDs for closure. When a PLD is submitted for closure after appropriate actions are taken on the lot, it goes through an approval loop to representatives from multiple teams. Everything is done through the URL link sent via e-mails. If the PLD is approved, the lot is taken out of that special location in MES, which then can be shipped and will show up as shippable material. Various reports are provided to view PLDs by equipment, process, lot, assignee, etc.



FIG. VIII: PROBLEM LOT DISPOSITION SYSTEM

UTILIZATION SYSTEM
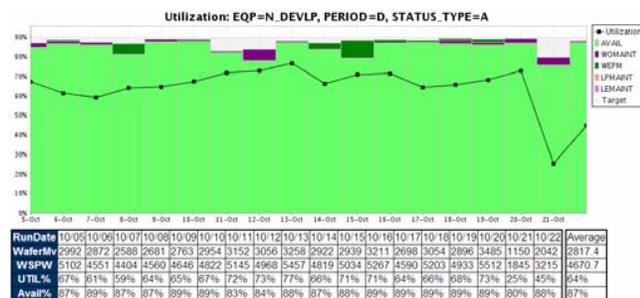


FIG. IX: UTILIZATION SYSTEM

This system provides four of the most important parameters for manufacturing: Equipment availability and utilization, lot moves and starts as shown in Fig IX. Utilization is calculated based on the timing model developed by our industrial engineers and is calculated for every tool id, tool type

and custom group. The time period can be monthly, weekly, daily or shift wise.

MANUFACTURING REPORTS

We have developed many web reports that provide real-time data to manufacturing operations in a dash-board like fashion; where summary data can be drilled further down to get detailed information. Some of the reports are shown in Fig X, XI & XII:
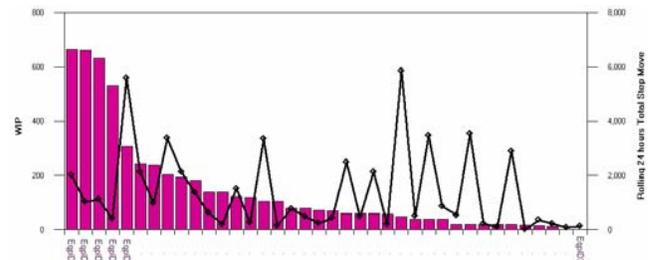


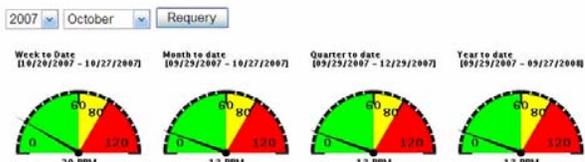FIG. X: WIP & MOVES BY PROCESS/EQUIP TYPE/LOCATION



FIG. XI: QUALITY METER



FIG. XII: EQUIPMENT STATUS

CONCLUSIONS

Factory automation is a valuable tool that can be applied to many areas across a semiconductor fab. With some creativity, and inputs from manufacturing and engineers, there are numerous ways systems can be created to save time, improve yield, and help improve processes.