Factory Automation for Overall Fab Efficiency

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Abstract

Factory automation in semiconductor manufacturing can be applied beyond just preventing human errors for wrong recipes. It can also aid process enhancements, improve throughput and overall equipment effectiveness (OEE), save engineering time and precious consumables, troubleshoot process or equipment problems, and much more. This paper describes how Skyworks has achieved these through various home-grown software applications to improve overall fab efficiency. Compound semiconductor fabs generally do not have advanced technology tools or big automation budgets like Si fabs. This requires us to be more creative in our factory automation approach.

Precious Metals Reclaim Tracking

This system has two sub-systems:

1. Evaporator Reclaims Tracking

   This home-grown system keeps track of the amount of precious metals consumed in each of the evaporator chambers and the amount of precious metals deposited on the wafers. Based on these two, it calculates the theoretical amount of precious metal to be expected in reclaim. It then compares the theoretical reclaim value against the actual to calculate reclaim efficiency and provides detailed data for troubleshooting when the efficiency is below the goal.

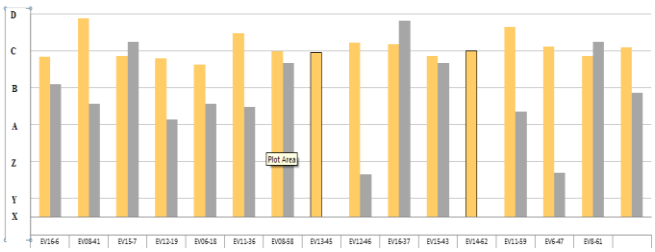

Fig. 1 Precious Metals Reclaim Tracking

2. Reclaim from Gold Plater Batch

   This system tracks the gold concentration of the bath in the gold platers in real time and calculates theoretical expected reclaim value when the bath is sent for reclaim. The calculation is based on the amount of gold added through the life of the bath and amount of gold deposited on wafers. It allows users to input sample concentration and actual reclaim values, and calculates reclaim efficiency.

Inventory Management – Precious Consumables

This system keeps track of inventory at each location, and transfer and consumption at each one. We currently use this system for precious metals, but it can be extended to all precious consumables. There are several reports generated from this database – one report shows how much precious metal we have on site at each location, and how many days' worth of inventory that is based on last seven days of average usage. It also shows the trend of usage as shown in Fig 2.

Grams	Supervisor	FAB	Floor	Total	Usage (g/day)	Remaining (days)
AU_SPLAT	X.Y	X.Y	X.Y	X.Y	X.Y	X.Y
AU_DISK	X.Y	X.Y	X.Y	X.Y	X.Y	X.Y
AUGE	X.Y	X.Y	X.Y	X.Y	X.Y	X.Y
PT	X.Y	X.Y	X.Y	X.Y	X.Y	X.Y

Fig. 2: Inventory Management

Parts Out Manager

This is a tracking system for all equipment parts or any other item (such as reticles) that go out for repairs or cleaning. It has two main objectives:

1. Tracking parts sent out for repair or cleaning, and
2. Reporting vendor performance against their committed cycle times.

As parts move from one place to the other, whether it is from Skyworks to a vendor or from one vendor to the other, that data is entered into this system. Based on committed cycle-time and expected shipping time, this system calculates when a certain part is expected to arrive back and whether it is on schedule. An example report is shown in Fig. 3.

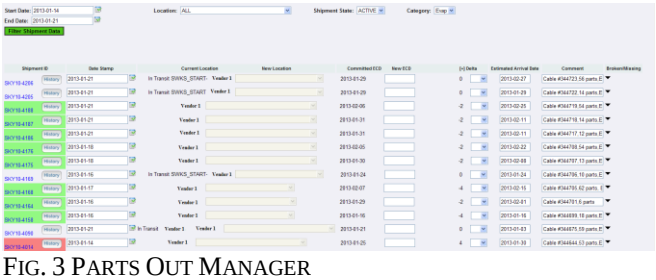

Fig. 3 Parts Out Manager

11 b

SINGLE POINT OF FAILURE TOOLS

This report periodically checks our qualification and capabilities plan against the tool availability in our manufacturing execution system (MES). It then sends notifications of current single point failure or one-of-a-kind tools, so that appropriate actions can be taken to prepare backup tools before the single point of failure tool goes down, as shown in Fig. 4.

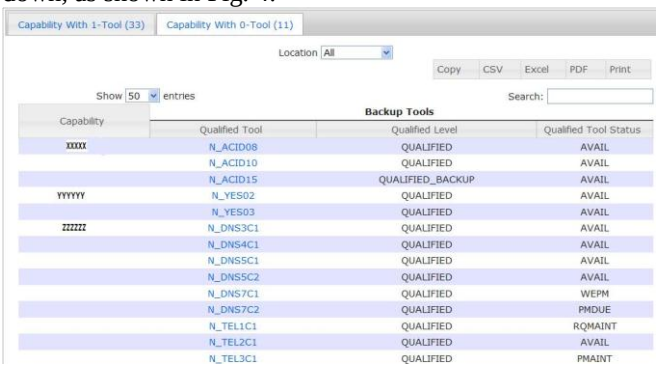

FIG. 4 SINGLE POINT OF FAILURE TOOLS

OEE IMPROVEMENT AT BOTTLENECK

To improve OEE at one of our bottleneck toolsets, we have provided real-time status updates of the state of the tool (processing, idle, etc.) and the expected time it is to remain in that state on big screen TVs in the fab. The expected time is coming from the time studies done by our industrial engineers. Different colors are applied to alert the technicians when a tool has been running a recipe, or idle longer than the expected time, as shown in Fig. 5. This information allows technicians to plan ahead, respond quickly to non-standard conditions, and maximize the throughput on that toolset.

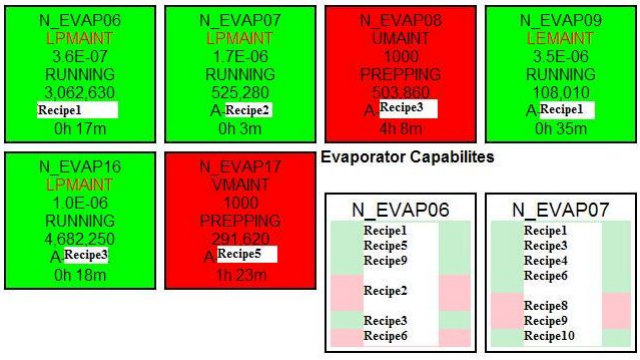

FIG. 5 EVAPORATOR STATUS AND DURATION INFO

PRECIOUS METALS CONSUMPTION CONTROL

To track and control the consumption of precious metals, we have created control charts on our intranet that show the consumption of precious metals for each run during the last 24 hours, see Fig. 6. That is reviewed daily and trend charts are created (Fig. 7).

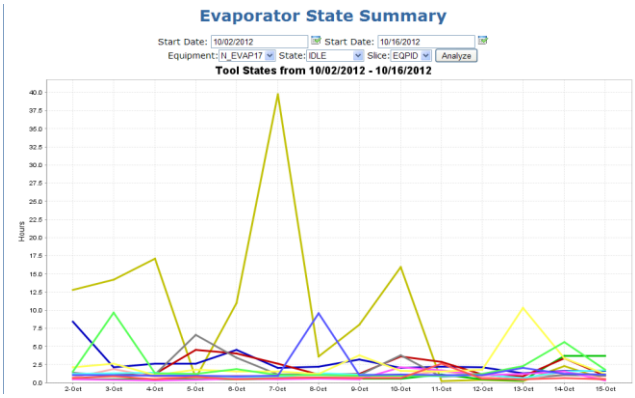

FIG.6 TREND OF EVAPORATOR UTILIZATION

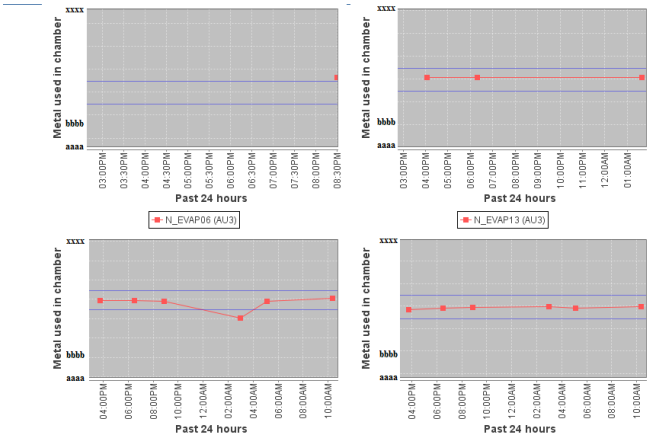

FIG.7 CONTROL CHARTS OF PRECIOUS METALS CONSUMPTION

The next phase of this system will take certain actions automatically such as disqualifying a melt, putting the tool down for maintenance, and notifying appropriate people when consumption goes out of control.

Another report shows weekly distribution of precious metal consumption across different types of lots as shown in Fig 8.

MELT TRACKING ON EVAPORATORS

To ensure high quality of wafer processing, we track our melts closely for qualification level (such as production, engineering, etc.), weight, and age – both in terms of time and number of runs that used a certain melt. We track their location as well for traceability. This information allows us to correlate quality of the wafer to any of the parameters and be proactive to prevent issues from occurring. Since we have automated our evaporators through CIM, any disqualified melt will not be allowed to use. Phase II of this system will automatically disqualify a melt based on a certain number of runs, which would require engineering to evaluate and re-qualify if required.

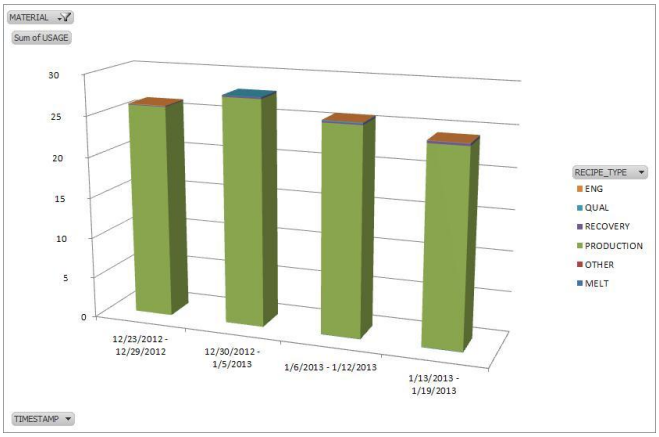

FIG. 8 DISTRIBUTION OF PRECIOUS METALS CONSUMPTION

INVENTORY MANAGEMENT & CONTROL OF SPARE PARTS

In order to manage the inventory and cost of equipment spare parts and expensive consumables and to ease ordering of spare parts, we have developed a Web-based parts ordering system. This allows our technicians and engineers to search for a spare part and order it from the warehouse once they find it. Like any e-commerce application, users can see pictures of the parts to ensure they are ordering the correct part, and once the order form is filled and submitted online, this system will then print the order request in the warehouse. This order request shows the warehouse the picture and location of the part, along with the requestor and contact information for delivery, as illustrated in Fig. 9.

Based on this data, we provide various financial reports showing the cost by tool, area, too-type, vendor, etc. Re-order quantities are also maintained in this system. The system also performs a daily check for parts with quantities less than the reorder point and sends notification to the appropriate people of such parts.

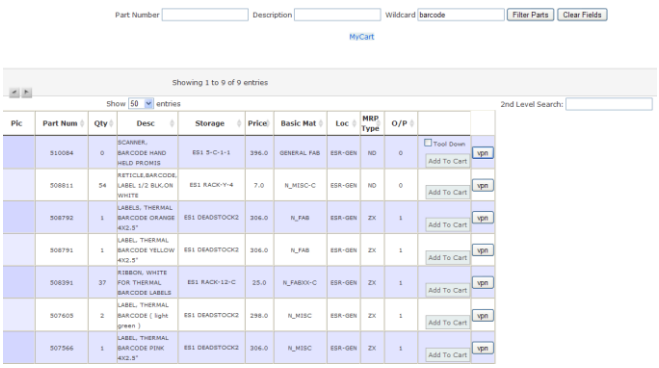

FIG. 9 SPARE PARTS INVENTORY MANAGEMENT AND CONTROL

DATA LINKS

The purpose of this system is to connect various types of process and measurement data about the same wafer in each lot. This system has two main components –

1. Connecting epi, process, metrology, and DC & RF PCM data
2. Connecting in-process inspections to probe data

Every epi wafer's identifier and its test data are associated with its Skyworks' wafer ID and with process data at various steps in fab. Once the wafer reaches PCM test, its DC and RF test data are linked to the epi and process data as well. This capability gives our engineers and testers enormous capability to troubleshoot a problem.

The other piece of the system connects the in-process inspection data to the probe data and creates a single wafer map that has ink-outs from both visual and electrical tests with appropriate reject codes.

ESD TRACKING SYSTEM

The ESD tracking system has two components:

1 Measurement

The measurement component runs on a handheld device such as the one shown in Fig 10. It allows the technician to scan the barcode of the location and enter the reading from the ESD tester. This information is saved in our database.

2. Reporting

The reporting component provides a graphical representation of the success rate as well as history by location.

CHEMICAL VERIFICATION SYSTEM

This system helps make sure chemicals are being poured into the right tank. The application runs on the same device as shown in Fig 10, but it has prompts for the user to scan the

FIG. 10 ESD MONITORING SYSTEM

bottle of the chemical and the barcode on the tank where they intend to pour before they do. In addition to matching the chemical to the tank, it also checks to make sure that the chemical has not expired and provides simple green or red screen indicators to the user. If the check succeeds, it also

11 b

makes a database entry for the "add" which can be retrieved for troubleshooting at a later time.

INVENTORY MONITORING

Out inventory monitoring system shows inventory by technology and location. There are various ways to slice the data. Different color stacks represent inventory of different processes, tool-type, or production area, depending on what the user wants. See Fig. 11.

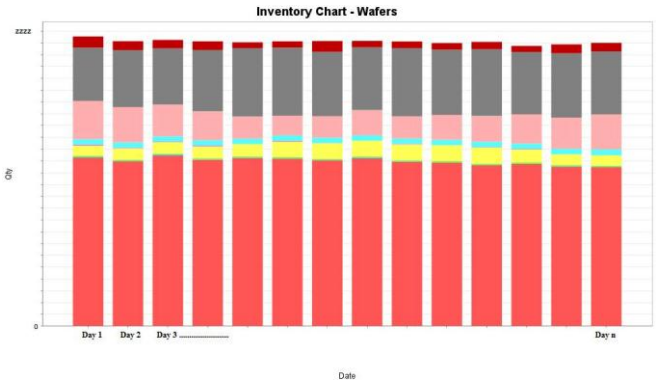

FIG. 11 INVENTORY MONITORING

RECIPE BUILDER FOR OVERLAY MEASUREMENT

At Skyworks, we are trying to minimize manual entries to prevent mis-processing and to improve productivity. So on our overlay measurement tools, the recipes are not created manually by the engineer. Instead, we have developed a recipe builder application that allows the engineer to upload the same Excel file he has created to list and maintain process parameters. The recipe builder application will build recipes for all layers from this input and push the recipes to all overlay tools without any manual intervention.

The benefits of this system are –

- Preventing typos in entering recipe input parameters
- Saving precious engineering time
- Ensuring all tools have the exact same version of the recipe

RETICLE TRACKING AND VERIFICATION SYSTEM

For traceability of reticles and to ensure the right reticle is used to process a lot at the stepper, we use RFID tags on reticle boxes and we have RFID scanners at all the locations a reticle can be. Every time a reticle is moved, it is scanned for the database to update its new location. A Web application is provided for the users to search and locate a reticle using this database. We use the RFID tags to also ensure that right reticle is loaded in to the stepper for the right lot. Although certain steppers could do this check on their own, a check prior to loading the reticle on the stepper saves time and prevents human errors.

CPK SYSTEM

We have automated Cpk calculations for our process and created a Web-based Cpk System. This system shows for each parameter its Cp, Cpk, mean, and standard deviation along with the count of data points, target, LSL, and USL by technology. Historical data is also available for quick comparison.

CONCLUSIONS

Used creatively, factory automation helps improve overall fab efficiency, not just the yields by preventing wrong recipes. With some creativity and inputs from manufacturing and engineers, we have created systems to improve yield, save cost and time, and help improve processes.

ACKNOWLEDGEMENTS

The author would like to thank the entire Skyworks' Operations team for their inputs to the automation systems.

ACRONYMS

OEE – Overall Equipment Effectiveness
MES – Manufacturing Execution System
LSL – Lower Specification Limit
USL – Upper Specification Limit