INFICON

TECHNICAL NOTE

FabGuard™ Sensor Integration and Analysis System: Return on Investment

RETURN ON INVESTMENT REALIZED WITH DETECTION OF FIRST PROCESS FAULT

FabGuard improves the cost of ownership (COO) of a semiconductor manufacturing tool by providing process enhancements, excursion detection, and statistical monitoring that lead to improved tool utilization, which in turn, leads to an improvement in overall equipment efficiency (OEE).

The amount of money saved depends on many factors, but FabGuard is uniquely positioned with its *in situ* monitoring capability and real time analysis to maximize the savings associated with tool data collection and sensor integration. Additionally, FabGuard is supported by a highly skilled and process knowledgeable staff of applications engineers.

Savings often come from simply detecting out-of-spec conditions. FabGuard looks for air leaks, inborn contamination, MFC failure or "ringing," cryopump regeneration, and preclean chamber effectiveness.

DRAMATIC REDUCTION IN DOWNTIME WITH FABGUARD

Each semiconductor facility computes ROI in a different way. Therefore, some variables must be translated to fit the model of a company's accounting system.

For instance, detecting a photoresist contaminated lot headed into a PVD tool might represent the potential loss of $150,000 in product wafers. However, that may only represent a 0.1% loss of production capability for the fab. In most cases, a fully integrated FabGuard installation with RGAs on a PVD production tool has been able to detect an average of 2.5 completely un-ashed wafer lots per year. Wafer lots which have been partially ashed (some residue left behind) are a subtler problem to identify and usually result in reduced product yield and tool downtime once the contamination has been detected. Performing a wet clean to remove residual photoresist on a tool removes a tool from service for 24 hours, and the cost of lost tool utilization is easily identifiable in a fab. Links to yield have been accomplished by quantifying the amount of residual photoresist remaining on product wafers and correlating these amounts to sheet and via resistance.

FabGuard with RGAs on a PVD tool generally results in a reduction of 120 hours of downtime per year. This equates to a 1.4% improvement in raw tool utilization over the course of a year.

An independent study[1] on the cost of yield loss is shown below. Fab yield losses of 50% and 5% are modeled. Actual losses are proportional to the time it takes to detect the fault responsible for the yield drops. From the time a problem

Detection/Analysis Technology	Maximal Localization Time (days)	Maximal Localization Time (minutes)	50% Yield Assumed Loss loss rate ($/min.)	Total Loss Per Incident (M$)	5% Yield Loss Assumed loss rate ($/min.)	Total Loss Per Incident (M$)
Functional Test	50	72000	10000	720	1000	72
Parametric Test	50	72000	10000	720	1000	72
Short Cycle E-test	7	10080	10000	100.8	1000	10.08
In-line Inspection/Review	1	1440	10000	14.4	1000	1.44
In situ	0.0007	1	10000	0.01	1000	0.001

[1] Strategic Options for Users and Suppliers of APC Technology, Charles Weber, 1999

originates to the time that problem is detected is dependent on the detection technology employed. For example, 7 days may elapse before a process-related problem is detected by short cycle testing. The cost of not knowing a problem has occurred is measured in the total cost of lost product. As the table shows, catching the problem at functional test produces a $72M loss whereas FabGuard, while catching the problem *in situ*, reduces the loss to $1,000.

This model is consistent with incidents that FabGuard has been employed to prevent from recurring. For example, in three separate cases product losses due to improperly deposited films were observed. The loss per incident averaged approximately $3 Million USD. In each case, the problem was isolated to a single tool where the problem went undetected for several days. Additional costs that are difficult to quantify were also incurred, including lost tool time to localize and isolate the problem source.

It is important to note that in all these incidents, the process of detecting these problems provided no protection against future occurrences of the very same problems. Prevention, however, has been assured by the installation of FabGuard. **ROI for the entire installation is very nearly equal to the cost of an incident on a single tool**.

PROCESS OPTIMIZATION

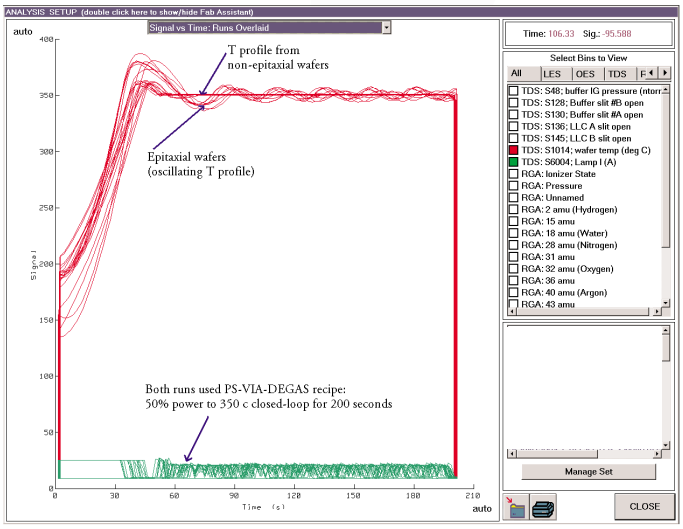
The process optimization capability of FabGuard and its integrated sensor platform is clearly associated with cost savings. Most software packages simply offer data in the raw format or look for out-of-spec conditions. FabGuard can be used to optimize processes and streamline the preventative maintenance process. This directly improves upon the OEE of the tool.

In example one, the degas chamber was set to run for 200 seconds at 50% power to properly degas the wafer. Using FabGuard and an integrated RGA, an on-site applications engineer from INFICON working with the customer was able to determine that after 120 seconds of degas time, the wafer was fully degassed and there was no reason to continue. The results are a 40% improvement in throughput for that tool when that product type is run, with no adverse effect on yield.

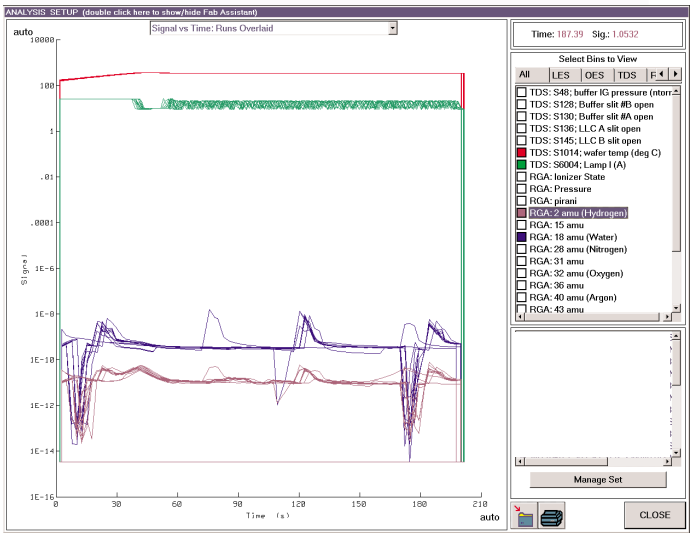
INFICON has a long history and an extensive installed base in semiconductor facilities around the world. Each region is staffed by applications engineers with years of fab experience and sensor expertise. INFICON application engineers are able to translate FabGuard data into specific help for each customer. INFICON is unique among software providers in the level of process expertise and tool diagnostics.

Example two shows the degas chamber and the temperature profile of two different types of wafers: epitaxial and non-epitaxial. The variation in the temperature profile shows that for semiconductor fabs running various types of products, recipes may need to be modified for substrate differences.

This example uses data gathered from the tool using the SECS communication to the tool and gathering the appropriate SVID.



Example 2 (above): Epitaxial and non-epitaxial wafer temperature profiles.



Example 1 (left): The jumps in the signal represent chambers opening and closing for normal tool operation. Note that FabGuard ignores these events as normal and does not generate a fault condition.

The cost improvements in this example are the ability to streamline processes, modify recipes according to product, and enhance yield associated with those improvements. For facilities with a wide variety of product such as a foundry operation, the ability to readily see process differences based on wafer type could create a competitive advantage.

RECIPE OPTIMIZATION

FabGuard is also used to maintain process recipes. FabGuard is able to read process set points and verify that the tool has not been mal-adjusted or incorrectly setup after a PM, or any other time. This has helped to reduce the human error that occurs occasionally. Millions of dollars are lost every year due to this simple and often overlooked issue of OEE improvements.

These examples are real applications and data from customers without proprietary details. FabGuard directly affects these variables to create an ROI model. The more integrated FabGuard becomes, the more it offers as a return on investment. Along with the variables are improvements that can be expected based on both a fully integrated FabGuard installation using *in situ* sensors and with only polling SVIDs from the tool. The range in percentages in the following table shows the overall improvement in production capability associated with installing and running FabGuard on a tool.

Some of these variables relate to revenue improvements and others relate to cost savings. Process excursions relate more to cost savings directly, hence ROI can be influenced directly by catching an excursion where the loss of a wafer lot can be easily computed.

FabGuard can be installed, tested, and verified in a short period. A complete installation, which involves data collection using SVIDs with the appropriate analysis, is usually completed in ten days, provided wafers are being run on the tool with production recipes. As recipes change, FabGuard analysis is easily adapted to reflect the new recipe, with little or no loss of monitoring capability.

FABGUARD CAPABILITIES

- **Multi-Sensor Control:** FabGuard offers a consistent user interface for the control of *in situ* sensors such as residual gas analyzers, optical emission spectrometers, particle detectors, and RF diagnostic probes. These sensors offer many capabilities not found on a tool and are able to help make continuous improvements to tool operation as well as maintain vacuum and process integrity.
- **Flex-Logic Signal Conditioning (FLSC):** This is a method for combining sensor data, mathematical computation, and Boolean logic to create powerful analysis routines for data analysis. No other software offers the ability to easily combine data from various sensors along with information gained from polling SVIDs from a tool to create robust and normalized analysis routines. Some chamber drift is normal in a tool. Flex-Logic signal conditioning allows FabGuard to take normal drift into consideration, so that no false fault indications are signaled. Pattern recognition software is more likely to give these false signals.
- **Real Time Analysis:** FabGuard real time analysis ensures that each wafer is protected or monitored for process excursions. It is usually used for endpoint or contamination control.
- **SPC Analysis:** This is a statistical analysis for SPC tracking that gives a longer-term view of the health of the process, wafers, and tool itself. It can be used to identify various trends for preventive maintenance, as well as setting control limits on chamber aging.

Variables	Full FabGuard™	SVIDs Only
Tool throughput	0.5 - 1.2%	0.3 - 0.7%
Wafer yield (not including major loss)	1.4 - 3.0%	0.3 - 2.0%
Process excursion, lot based [1]	0.1 - 2.0%	0.1 - 2.0%
Optimization improvements, [2]	0.5 - 0.8%	0.2 - 0.3%
Process set point verification [3]	0.1 - ? %	0.1 - ? %
Total	**3.5 – 7.0%**	**1.0% - >5.0%**

[1] This differs from yield where a major tool malfunction causes the loss and scrap of multiple lots of wafers.

[2] Optimization differs from tool throughput in the area of process refinement and not process readiness.

[3] This is basically a human error issue and can vary from location to location.

- **Run-by-Run Analysis:** This creates a very powerful method for control of processes, because the data represents the entire run and not only a single point. It is used for complex analysis functions for viewing entire data sets.
- **SQL Database:** The Microsoft SQL database creates the ability to compare analysis results from various tools and chambers. Wafer analysis and the history of wafer lots can often help pinpoint where process problems may have occurred.
- **eFabGuard™:** eFabGuard allows INFICON applications engineers to remotely monitor and maintain FabGuard analysis recipes, as well as help on-site engineers troubleshoot process-related problems. This is accomplished with a dedicated Internet connection to a FabGuard server along with an INFICON secure, commercially available Virtual Private Network (VPN).

SUMMARY

FabGuard offers many distinct ways of providing ROI. Catching process excursions, providing information for process optimization, reducing the likelihood of human error, are all ways that FabGuard helps keep process tools running properly. With the increased level of technical ability of INFICON applications engineers, we are able to help maintain FabGuard installations effectively, as well as help troubleshoot process problems on tools. Our robust analysis, fault detection and classification, and SQL database are all tools available for every installation, making FabGuard a very effective data collection and analysis system.

INFICON The Instrumental Difference®

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