FAULT DETECTION AND CLASSIFICATION IN ETCH TOOLS

by

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ABSTRACT

During my 18-month tenure as a coop engineer in the Advanced Process Control module and the Etch module at Advanced Micro Devices, I played an important role in the advanced process control mechanism. The objective of my thesis project report is to explain the features and benefits of the fault detection and classification mechanism, with illustrations of its advantages in the etch module of Fab 25 AMD.

Advanced process control (APC) is a novel technique in the semiconductor industry. The crux of APC is that some wafer defects do not get detected until the end of the manufacturing process and that the health of a piece of equipment is an indicator of the quality of the product it produces. Since any adverse change in the tool health would have a negative impact on product quality, it would be possible to immediately detect a wrongly processed wafer and take corrective actions, by monitoring equipment health.

Using a unique model-based technique, real-time monitoring mechanism, and efficient classification strategies, the FDC Department at AMD has made it possible to accurately determine the health of a piece of equipment in real-time. Equipment-related problems are immediately revealed when the equipment health falls outside a statistically derived limit, which is calculated from in-process data when the equipment is healthy and operating normally.

The report gives an idea about my specific roles as a coop engineer, scaling different proportions in various steps of the FDC implementation

mechanism. The steps involved in the setting up of the FDC mechanism and the continuous real-time monitoring of the etch plasma stripper processes have been clearly outlined and a few instances of potential faults detected through FDC have also been explained. Current shortcomings and suggestions regarding future enhancements to the existing FDC mechanism have also been presented.

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

Semiconductor manufacturing in a high volume and a high product mix production environment is an extremely competitive business with respect to product quality, equipment productivity, and speed of innovation. Operating at the technology limits in feature size and using new materials on 300mm wafers will continue to present challenges in the process control area. The sophisticated processes need stabilization by many different approaches in equipment and process control, new sensor systems, in-situ and integrated metrology, and fab automation. The increasing demand for fewer defects, higher throughput, and cost reductions in semiconductor processing has sparked steady interest in a new concept called advanced process control (APC). Many companies are evaluating APC's potential to increase capacity while investing little capital. AMD has created a niche for itself in the advanced process control arena by being one of the leaders in implementing APC successfully in its fabs across the world.[1]

APC includes both Run-to-Run (RtR) control and Fault Detection and Classification (FDC) applications.

Run-to-Run (R2R) Control is a form of discrete process and machine control in which the product recipe with respect to a particular machine process is modified ex-situ, i.e., between runs, so as to minimize process drift, shift, and variability. In effect, the inputs and outputs of each process run are taken into account by the R2R controller at the end of each run. From this data, the controller makes adjustments to the process in order to improve the effective output and increase yield at the end of the next run. By repeating this process in between each run, one can minimize process drift. This type of control is a critical component of the hierarchal scheme that is widely suggested for control in the semiconductor-manufacturing arena.

Run-to-Run process Control at AMD is able to compensate for drifting processes where output variations are correlated. The variation is typically caused by changes in the processing environment. For example, in a deposition process, the reactor walls may become fouled by deposition as many batches are processed. This slow drift in the reactor chamber state requires small changes to the batch recipe in order to ensure that the product outputs remain on target. Eventually, the reactor chamber will be cleaned to remove the wall deposition, effectively causing a step disturbance to the process. Just as the Run-to-Run Controller compensates for the drifting process, it will also compensate for the step disturbance to return the process to target after an environment change.

Another major classification of the APC system at AMD is the Fault Detection and Classification (FDC) mechanism, about which this report is based on. FDC monitors the real-time performance of a tool to ensure that its performance does not result in misprocessing.

Overall Equipment Efficiency (OEE) [3] is a metric of equipment performance. OEE is calculated by comparing maximum potential performance of a tool with actual output and production time. Incorporating FDC into the fabrication system has enabled AMD to improve overall equipment efficiency by monitoring equipment health and detecting emerging faults.

The need to consistently provide higher quality products at lower costs and reduced manpower requires new methods for analysis and control of the manufacturing process. With the aid of improved control, quality is improved and costs are considerably reduced. One such efficient control is Fault Detection and Classification, a method of automatically extracting and analyzing data to determine and assign the possible cause to faulty tool or process operation.

The importance of FDC mainly lies in reducing manufacturing costs. By providing an automated extraction and analysis of data, FDC systems can reduce scrap by detecting tool drift and misprocessing and improve equipment utilization by reducing unplanned downtime. In addition, better access to data creates the ability to assign excursions to their root cause, increasing the effectiveness of the engineering staff. It also reduces the test wafer requirements by providing a software determination of tool health.

1.1 Key elements of FDC system

Fault detection and Classification (FDC) is a type of APC method that seeks to ensure stable process performance. As opposed to run-to-run control methods that actively control process variables, a FDC system monitor variables during the operation of a process to ensure that its performance is as expected. Such monitoring enables detection of operational faults in real time, and facilitates interruption of the process before significant amounts of product are put into jeopardy of misprocessing.

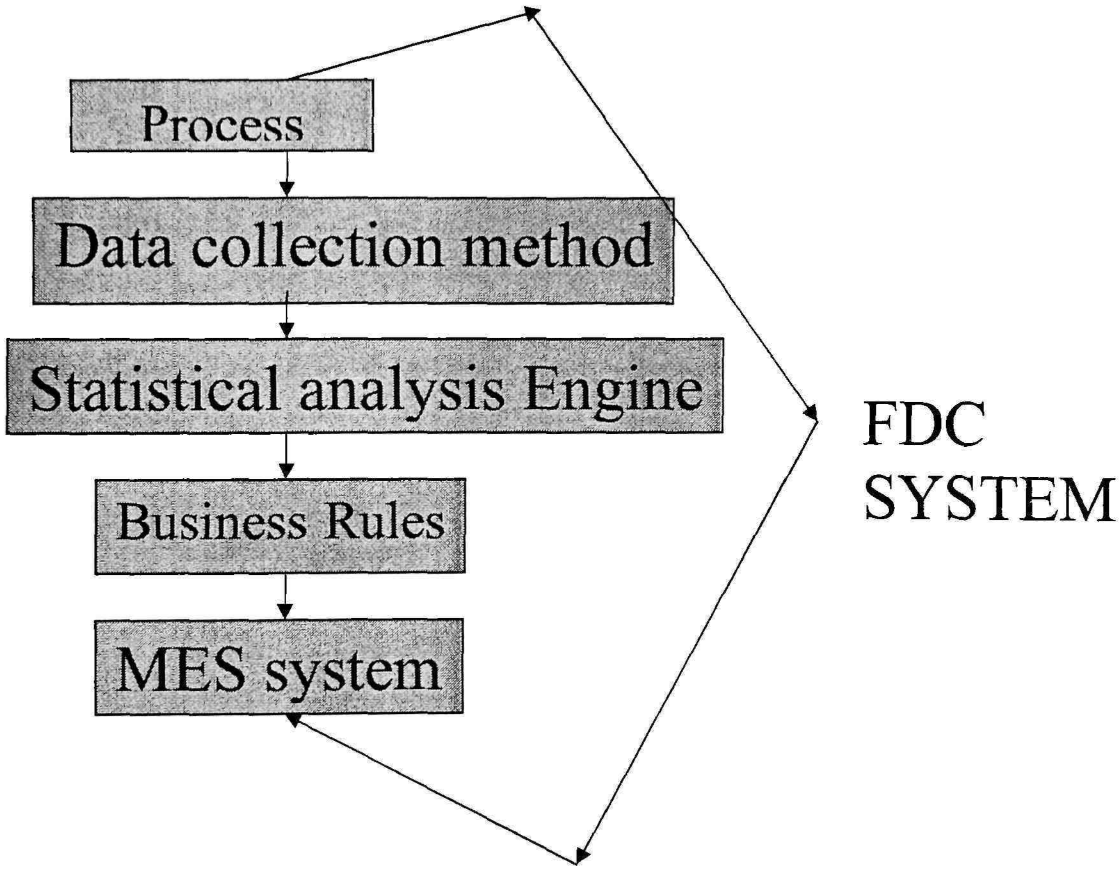

Figure 1.1. Key elements of a fault detection and classification system

The Key elements of an FDC system are the process tool, the Data Collection Method, the statistical Analysis engine, the Business rules, and the MES system [2] as shown in Figure 1.1.

The Process tool determines the availability of the necessary Status Variable parameters called the SVIDs. These SVIDs are necessary for the collection of the data related to the process such as the pressure, temperature, and gas flow information during the processing of the lot. Some important tasks during the FDC implementation were the acquiring of these SVIDs from the latest Software version that the tool ran on and converting them to a format compatible to the Data collection Software.

The Data Collection Method is an important aspect of a Fault Detection and Classification Mechanism. It determines the rate at which data is obtained for real-time analysis. In the case of the Plasma Strippers, initially the SECS-GEM based data collection method was used. Subsequently SXML based communication was implemented which brought down the number of communication glitches and also increased the rate of data collection. The current rate of data polling and collection on the Plasma strippers is approximately every 3 seconds.

The data that is collected from the tool is continuous real-time data. It gets archived in the FDC server for subsequent analysis. The statistical analysis engine to be used for data analysis is the most important aspect of an FDC system. The analysis mechanism could be univariate or multivariate. It was decided to use a multivariate analysis system for efficient fault detection and classification between the well-correlated parameters. Although the commonly available Excel/JMP software could be used for graphing and performing various statistical analyses, the sheer volume of the data and the need for frequent analysis necessitated the use of dedicated software for FDC. Triant's Modelware was used for doing the statistical analysis in the case of the FDC systems at AMD. The detailed description about the software and its applications has been explained later in the report.

The final goal of an efficient FDC system is the capability of the automatic tool shutdown mechanism based on the statistical analysis software's decisions. In order to have a foolproof tool shutdown mechanism, devoid of false alarms due to the FDC, a number of DOEs are conducted to ensure the robustness of the system. The set of business rules governing the decision making process of the FDC system is an integral parameter of the FDC mechanism. Workstream control charts were created for each chamber of every tool and the Triant Modelware software's tool health parameter was monitored and tracked within certain specified limits. Whenever the tools working condition deteriorated or when the process parameters started to drift, the tool health value on the control charts drifted out of the control limits, creating an alarm. This alarm can be used to put the tool down to maintenance immediately.

Finally, the MES (Manufacturing Execution Systems) is a very important part of the FDC system. Using current and accurate data, an MES synchronizes plant activities as they occur in the manufacturing cycle. In the case of the FDC mechanism, the MES system makes sure that the Equipment interface, the tool and the FDC data collection system are working in tandem. The system has been designed in such a way that even if there is an occasional glitch in the FDC data collection mechanism, it does not impact the tool or production. Every tool has an EI engineer associated with it who takes cares of the additional scripts to be included in the tool's baseline for the incorporation of the FDC mechanism on to that tool.

1.2 Benefits of FDC

The fault detection and classification mechanism at AMD has contributed a number of benefits to the manufacturing process.[3] Some of its advantages are :

1. Reduced scrap due to equipment faults

While faults or tool breakdown are rare in a fab, there is every possibility for a piece of equipment to occasionally malfunction. In such a scenario, the alarm system of *the FDC system* can be set up to halt the tool in case of a serious fault. Automatically halting the tool reduces the potential scrap from one or more lots to only one or two wafers. Warning alarms can also be used to flag lots or wafers for further investigation down the production line.

2. Reduce the number of Qual Wafers

Since the model-based FDC approach continuously indicates the consistency of the tool's performance, there is very less need to run a Qual wafer just to make sure everything is still on target. This reduces much of the labor and time involved in the process. It also ensures that a significant amount of human involvement and possible errors are avoided.

3. "See" into the tool as it operates

One of the most attractive characteristics of the FDC system is that the process engineer can look into the working of a tool in real-time during its operation. With the aid of the FDC system, even wafer-by-wafer process data can be instantaneously observed and analyzed.

4. Compare tools or chambers

The off-line model creation and validation utility of the FDC system, helps in the easy analysis of a tool, without any tedious manual comparisons or guesswork. The model created for the best tool can be used as a reference to analyze data from a similar tool or chamber. By viewing the comparison results, we can quickly see if and how the processes differ.

5. Reduce the amount of raw data to be reviewed

Reviewing all the raw data gathered for any one tool would be a tedious process requiring huge amount of time. The bulk of data is reduced when a single value called the system health metric is created using a series of modeling algorithms. From dozens of input values, *the FDC system* calculates a single system health number for each model.

6. Reduced down time

After maintenance, *the FDC system* allows the process engineer to quickly gauge if the tool is performing as it should, by comparing post-maintenance performance of a small number of test wafers, without waiting for metrology results. This ensures that there is a smooth passage of the production wafers down the line without any delay.

7. Lengthen the maintenance cycle

The FDC system is an efficient indicator of when maintenance is required. It helps in using real-time data to plan down time for preventive maintenance or repair and also aids in monitoring system health or other key chamber statistics to determine when maintenance is required, instead of basing the work cycle on a fixed time or number of wafers.

1.3 Tasks in the Fault Detection and Classification Mechanism

My role scaled to various proportions at different levels of the FDC process. In the front end of the FDC mechanism, I had to mainly coordinate with the FDC and the etch engineers with issues such as

- Obtaining official permission for the project,
- Substantiating the need for FDC and evaluating the ROI, return on investment of the project,
- Setting up of FDC infrastructure,
- Determination of collectable parameters/SVIDs,
- Running design of experiments (DOE).

In the front end of the FDC mechanism, I had to play a major role (owned the plasma strippers-FDC) in the following tasks

- Data collection set up,
- Verification of collected data,
- Setting up of models for each recipe on each tool,

- Monitoring and modifying models with current process trends.

Apart from the above-mentioned tasks, I was in charge of the continuous/On-going tasks, which were

-Daily monitoring of the tool health charts from each tool,

-Comparison of process trends of each tool and generating weekly reports,

-Identifying faults/outliers and assigning causes to each of them based on Modelware data,

-Writing detailed reports and aiding in the fault-resolving process,

-Propagation of FDC on to other toolsets,

-Represent the Etch module for the FDC meetings and tool specific meetings.

CHAPTER 2

ADVANCED PROCESS CONTROL AT AMD

2.1 AMD's Six-Step FDC Development Process

The Fault Detection and classification mechanism at AMD basically consists of a series of 6 fundamental steps [4], which are as follows

2.1.1 Project Definition and target acquisition

The need for a FDC system is investigated and the initial targets are identified. This initial step is a priory risk assessment made by the module engineer and the FDC engineer that evaluates the currents risks that would be mitigated by the implementation of an FDC system. Various methods such as Failure mode and effect analysis (FMEA) and Design of experiment (DOE) methodology are used to quantify the risk and a clear definition of the target is obtained.

In the case of the plasma strippers and the etch sinks, DOEs were conducted to substantiate that the etch tools were ideal candidates for FDC implementation. The goal was to identify the significant variables that need to be monitored and their sensitivities to the process. Around 5 to 10 variables per chamber were identified to be critical factors affecting the process.

2.1.2 Establish Current capabilities and required modifications

In this step, an assessment is made of the availability of the targeted data at the required frequency. The current FDC capabilities of the tool are thoroughly reviewed. If minor modifications can accomplish the objectives, they are implemented with little cost and engineering time. If add-on FDC systems or sensors are required to collect data previously not accessible or at sampling rates unavailable from the current tool or equipment interface, then the complexity, cost and engineering time is worked out upon consultation with the process module.

In the case of the Plasma Strippers, it was found that the required parameters were readily available from the tool and there was no necessity for any add-on sensors and additional modifications. The required trace data could be supplied to FDC by the tool status variables (SVIDs) from the SECS port of the tool at an acceptable rate.

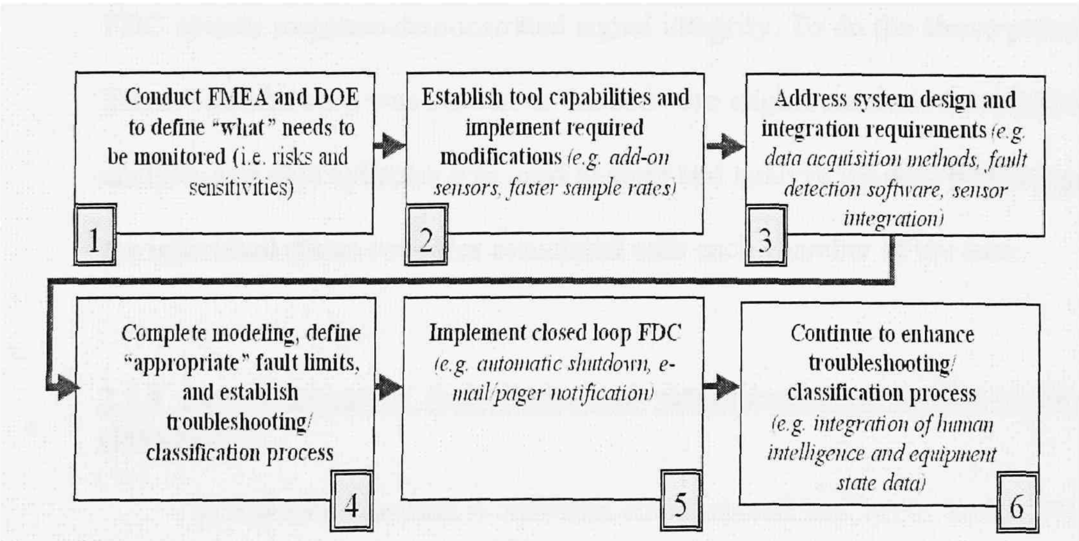

Figure 2.1 AMD's six-step fault detection and classification development flow diagram

2.1.3 Address system Design and Integration requirements

In this step, the specifics of the project such as the method of data acquisition, the fault detection software that will be used, integration issues for the software or add-on sensors that must be resolved, etc. are defined and worked out. Cost effectiveness plays a major role to balance the cost and time required to implement an FDC system and hence the system requirements, data output and data analysis are kept as simple as possible.

Data is automatically extracted from the tool as a series of particular measurement values versus process time. This is done via the SECS-GEM communication approach.

In the case of the Plasma strippers, an initial FDC system was installed and tested. Data associated with the process recipes, lot activity, etc., that will be used for FDC was collected. Inducing known faults and documenting the FDC system response demonstrated signal integrity. To do the above process, Triant's Modelware was chosen as the software engine for fault detection and analysis and data collector was used to store and analyze the data pertaining to the individual status variables associated with each chamber of the tool.

2.1.4 Determination of fault limits and establishment of trouble shooting classification

In this step, the data is collected and analyzed and limits for the initial FDC system are determined and tested. This is the phase where the FDC engineering module works closely with the individual module process engineer to demonstrate the ability of the FDC system to provide the benefits sought.

Individual data signals are monitored as a time series. This requires that the system integrate signals according to the recipe run on each tool and allow the engineer to plot each individual signal to verify signal integrity. This happens to be the most important step in phased implementation. SPC methods applied to individual signals and monitored by the module engineer allow for improved equipment operation and understanding. It also helps define specific actions and responses that should be taken if multivariable modeling methods are later applied as the actual fault detection mechanism. It is in this step that the automated alarms, notifications and tool shutdown criteria are defined and tested based on business rules determined by the FDC module upon consultation with the process module.

Some of this data can be sent to the factory Workstream system for SPC charting, providing familiar error actions and tool halts by SPC violations. Any system capable of halting a tool requires a trouble-shooting guide (TSG) associated on necessary actions.

2.1.5 Implement closed loop FDC

In this step, the control loop is closed down so that the error actions such as alarms, email/pager notifications, and automated tool shutdown are enabled. This phase of Advance process control requires the coordination of the equipment interface and APC script systems to enable the automated actions whenever a fault is encountered. Each time a fault is encountered and rectified, the TSG gets populated with different kinds of faults and identification mechanisms for efficient subsequent fault detection and classification.

The implementation of closed-loop FDC is undertaken only upon verification that the entire FDC system is foolproof and that it does not generate false alarms during the tool's normal operation which would defeat the basic purpose of FDC implementation.

2.1.6 Continuous Improvement Programs

The final step in the FDC implementation process is actually a never-ceasing step wherein the whole system is continuously monitored and any glitches in the system are promptly identified and rectified for efficient working. This requires the process module and the FDC engineer to periodically evaluate the system's efficiency and use the experience and intelligence gained over time to improve the FDC system characteristics. The process module personnel are provided with the hardware and software necessary to gain an understanding of the system and to use it for their analysis of the process. Since the goal of FDC is to prevent any scrap or degradation of the device, adequate safeguards and precautions are taken that the system constituents such as the Models, Data and other system characteristics are not tampered bringing undesirable changes.

2.2 Process Control Methods

There are two major types of APC systems statistical process control (SPC) and model-based process control (MBPC)[5]. SPC can be broken down into univariate and multivariate fault detection methods.

2.2.1 Fault Detection through Univariate SPC

Univariate SPC [5] systems are based on the idea that variations of a controlled variable (variations that affect a process all the time and are essentially unavoidable within that process) have a common cause. SPC allows the normal variation of a controlled variable within acceptable limits and detects any assignable cause of abnormal variation of the controlled variable as soon as possible. The technique is characterized by the creation of control charts with a target value and upper and lower control limits that plot individual monitored variables.

Because univariate SPC leads to the creation of as many control charts as monitored variables, it is of no value at the fab level, where a huge number of variables must be monitored, and of little value at the tool level because an engineer can monitor a maximum of only four charts at the same time. Moreover, of all control methodologies, univariate SPC results in the most undetected errors and false alarms, leading to wasted time. Also, the monitored variables must theoretically be independent, which is usually not the case in the semiconductor industry.

2.2.2 Fault Detection through Multivariate SPC

Multivariate SPC [5] is superior to univariate SPC. Rather than create separate control charts for each variable, multivariate SPC uses global control charts that represent as many variables as needed. Moreover, multivariate SPC is much more precise than univariate SPC in detecting errors and avoiding false alarms. Finally, multivariate SPC takes into account the dependencies among monitored variables.

Multivariate methodologies have their limitations, however. While they generate almost no false alarms or undetected errors, they cannot indicate the origin of errors and are thus unable to automatically manage error occurrences. Detecting error origins with these methodologies can be so complex that engineers either require a very high level of expertise and intuition to use them or cannot use them at all.

2.2.3 Model-Based Process Control

MBPC [5] directly links product variables and process variables to models. This control method tries to determine the variables of a process from the characteristics of a desired output. Inversely, it also tries to predict product output from the process variables. These two applications are the basis for feed-forward, feed-backward, and real-time control. The power of the models is their ability to compare desired and real output variables.

Building models for MBPC requires a good knowledge of equipment and processes. While performing MBPC on one type of equipment may provide good results, doing so on another may provide unsatisfactory results.

Thus, performing MBPC requires that customers learn the method or that suppliers learn the processes, resulting in a slow, but foolproof method of fault detection.

AMD has implemented FDC in most of its FDC-installed tools, using a model based software solution called Modelware provided by Triant Technologies Inc, which is a leader in semiconductor equipment health monitoring and advanced fault detection software solutions.

2.3 Triant's Modelware

Triant's ModelWare [3] is a collection of software components developed to monitor equipment health and detect faults in semiconductor fabrication equipment. It operates based on the Universal Process Modeling, or UPM [13] technique, which is an inductive, or example-based, modeling technique which uses a reference library made of data collected from previous "good" lots, to describe how a tool normally operates. The resulting multivariate model defines a tool's expected behavior for a specific recipe, and allows the software to detect significant differences in equipment operation.

2.3.1. Modelmaker

The modeling software runs in real-time, calculating predictions of sensor readings and system health to any given operating condition, based on past tool behavior. Modelmaker is the GUI that is used to create models for comparing with real time data from the tool. The Modelware makes use of a reference data set that consists of samples that are the best operating conditions of the tool.

For every sensor sample, the software calculates in real-time, a prediction and normalizes the difference between the observation and the prediction to find the residual error. The normalized residual error is referred to as "Signal Health."

It calculates an index of system health based on the residual error of all the readings in the sample set and expresses the system health and the individual signal health as single metrics, reflecting how many standard deviations the collected signal is from the "ideal." These System and signal health readings are used to detect emerging faults and deviations. The software allows the user to specify the alarms based on fluctuations in system health and signal health. The dataflow in the Modelware FDC system can be represented

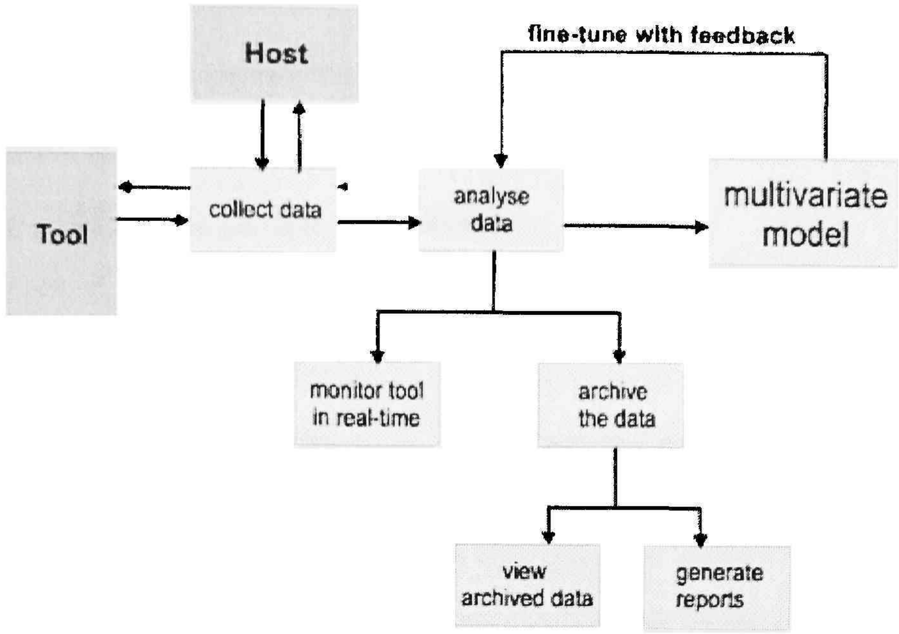

Figure 2.2. Dataflow in the Modelware FDC system [3]

Once the *ModelWare system* is set up on a tool, production and tool operation can be monitored continuously. Data can be viewed both in real-time and offline from any monitor on the system. The Modelware system and it components collect data from all the sensors that have been configured for collection in the Data Collector as shown in Figure 2.2.

Once the Data Collector has collected the data, it can be used for analysis. Data analysis could be done by simple SPC charting with alarms and specified limits. In the case of the FDC at AMD, multivariate models created using the Modelware software was used for data analysis. The FDC engineer decides the sensor properties that contribute to the model. The critical status variables are made active and the non-critical but essential parameters are made passive during the creation of the model. An active sensor contributes to the tool health, while a passive sensor does not. Tool alarms can be set for both the active and passive sensors to indicate any specific kind of shift from the normal operation that needs to be monitored.

2.3.2. Model Display

The tool operation and the specific sensor trend of any tool can be easily analyzed

in real time using Modelware's user friendly GUI called the Model-Display.

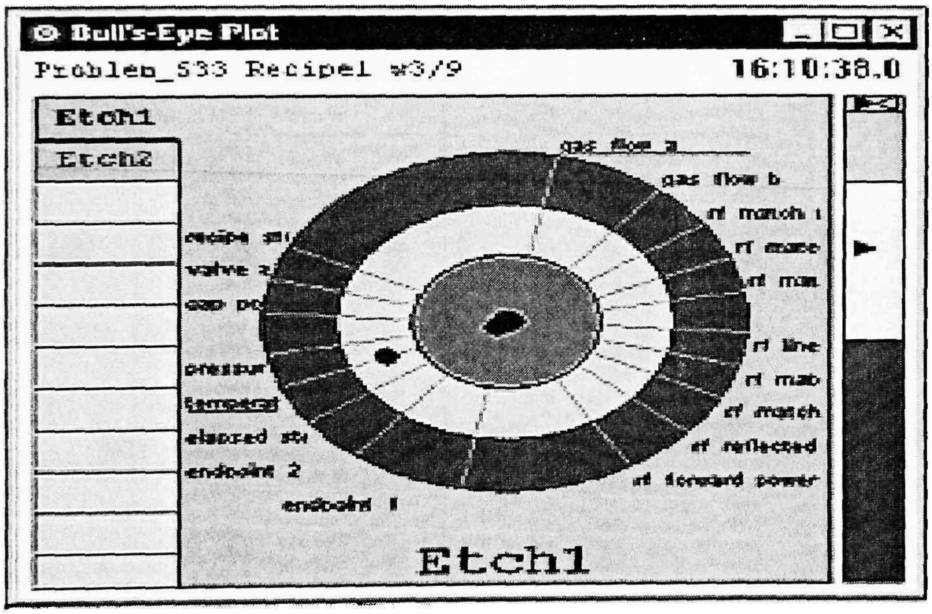

Figure 2.3. Modeldisplay bull's eye plot of the Modelware software [3]

Model Display is a utility, which gives an easily understandable visual display of the current operating conditions on a lot. It has a "Bull's eye" approach of representing the tools performance as shown in figure 2.3. Each of the parameters that are collected from the tool through the FDC data collection system, is represented by a dot on the Bull's eye chart and if the process deviates from the normal operating conditions, the specific parameter responsible for the drift, drifts out of the Bull eye's accepted Green region into the Yellow or Red regions. An alarm is produced when such an occurrence is noticed.

2.3.3. Modelview

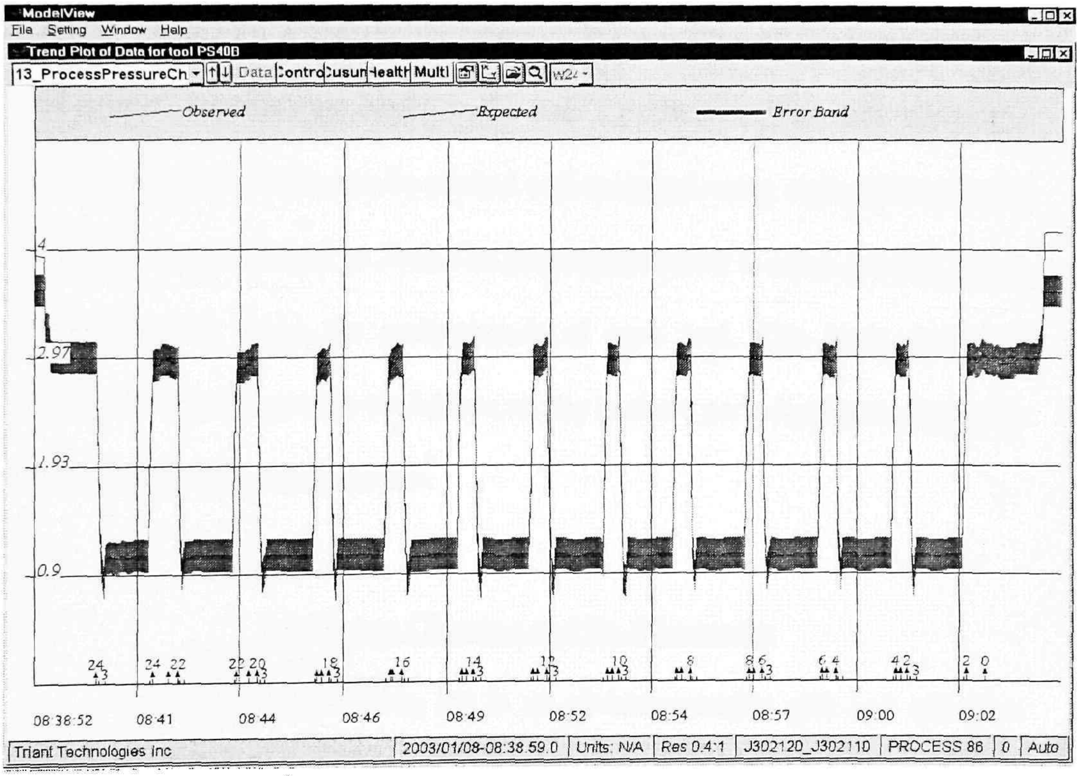

Figure 2.4. Modelview utility of the Modelware software [3]

The data that is collected can also be archived for detailed analysis to be conducted later. The Modelware software component called the MODELVIEWER helps in viewing the archived data. This GUI is very useful in looking at the individual sensor properties of the archived data. Various features such as the tool health, control parameter etc. present in the MODELVIEWER GUI helps in rapid data analysis and easy identification of the cause of a fault, if any.

2.3.4. Report Generator GUI

Modelware software has a GUI, which is useful in data analysis. The report generator GUI helps in doing graphical analysis of data pertaining to specific recipes for a specific time period. It scans through the huge database and collects specific data based on the user's preference. The data, which the report generator offers, can be plotted and analyzed using statistical software such as Microsoft Excel or JMP.The Report Generator is often used to create weekly reports about the performance of each tool. The tools operating conditions and the process deviations on the tool are periodically tracked with the help of the Report Generator.

2.4 Plasma Cleaning and Its Advantages

Plasma cleaning/etching [6] is an environmentally safe and effective technique for removing organic contaminants from a variety of materials and substrates. It is used for stripping, cleaning, and ashing in the semiconductor, hybrid, analytical chemistry, plastics, and optical industries. The plasma process offers several advantages over conventional chemical cleaning methods. Plasma provides a low temperature environment using electrical energy to promote chemical reactions rather than heat. Plasma also eliminates the dangers associated with wet chemistry and has the major advantage over other cleaning methods because there is no liquid waste, hence no expensive disposal. Finally, plasma is a simple process requiring little or no supervision.

The plasma process is accomplished through the use of a low pressure and an RF induced gaseous discharge. The specimen is loaded into the reaction chamber and the chamber is evacuated to a vacuum pressure of 0.1 - 2.2 torr. A carrier gas is then introduced into the chamber, raising the chamber pressure to 0.3 - 1.2 torr, depending on the application. RF power is applied around the chamber. This excites the carrier gas molecules and dissociates it into chemically active atoms and molecules. The mechanism employed in this process is one of ionization. The combustion products, which are completely dissociated and harmless, are carried away in the gas stream. The unique property of this process is that it occurs at relatively low temperatures without employing toxic chemicals.

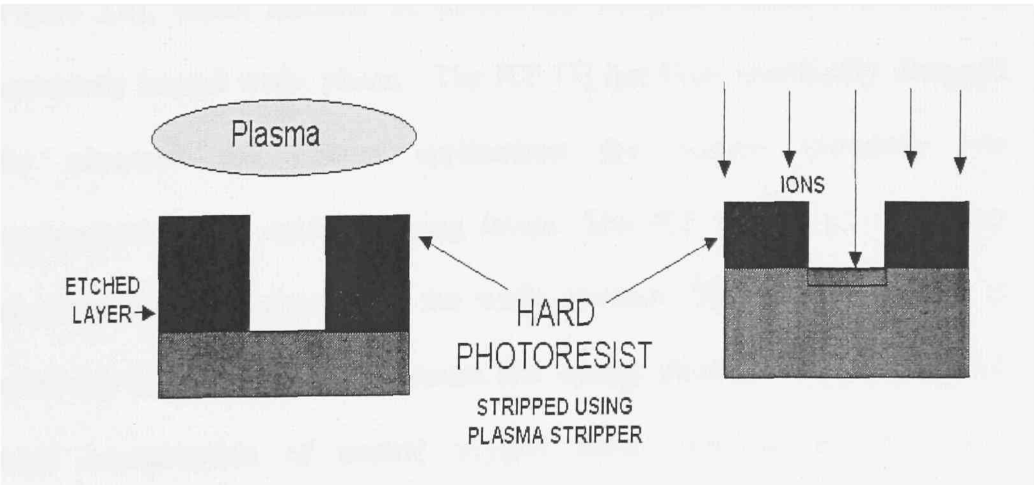

Figure 2.5. Plasma stripper stripping mechanism [6]

The process of plasma ashing, plasma stripping or micro-incineration is usually restricted to the total removal of organic matter by an oxygen plasma as shown in Figure 2.5; the products being carbon oxides and water vapor, which are volatile and pumped away by the vacuum system. Historically, the first application was for the removal of photoresist in the microelectronics industry. Photoresist is composed of organic compounds, essentially consisting of carbon, plus hydrogen and oxygen. Exposure to oxygen plasma eventually removes all the photoresist as volatiles leaving no residues, unless there are inorganic contaminants in the photoresist. The process is therefore totally dry and is also a means of concentrating inorganic contaminants in organic materials.

2.5 Mattson Plasma Strippers

The Process Chamber consists of the standard ICP configuration (see Figure 2.6), which includes an Inductively Coupled Plasma source and a resistively heated wafer platen. The ICP [7] has been specifically designed for advanced sub micron applications that require extremely low contamination and oxide charging levels. The ICP plasma is inductively confined several inches from the wafer surface. The source operates at relatively high pressures and creates low energy plasma, which generates a high concentration of neutral oxygen atoms and an extremely low concentration of ions. The neutral atoms created in the plasma are transported to the wafer by forced convection to strip the resist.

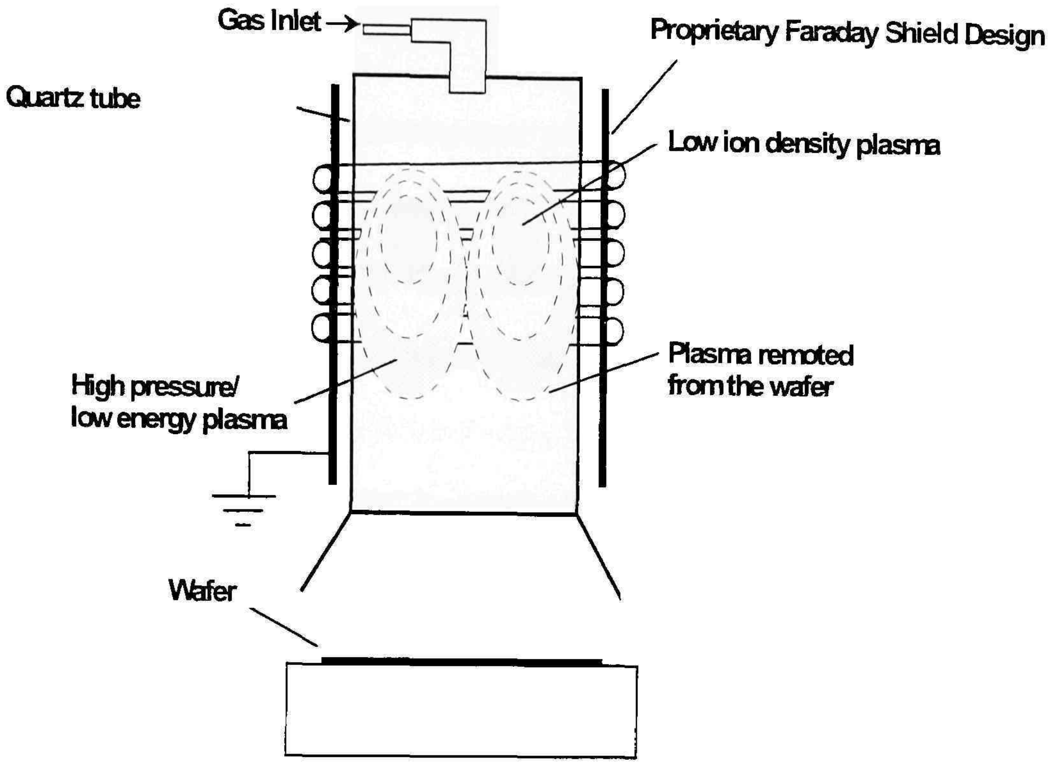

Figure 2.6 Mattson single chamber Plasma stripper [8]

Large quantities of wafers can be stripped using oxygen plasma. Oxygen plasma is very selective in etching photoresist over other semiconductor materials. Because many wafer processing steps require photoresist stripping, the Mattson Plasma strippers are used to meet high throughput requirements.

CHAPTER 3

FDC ON PLASMA STRIPPERS

The etch tool FDC development process goes through a number of iterations involving the coordination of the FDC engineers and the process engineers of the Etch module. The foundation to the development process is laid by dwelling upon the basic requirements for the system.

3.1 FDC System Requirements

For the plasma stripper FDC system, the following system requirements were figured out

Plasma stripper tool with status variables list

The status variables refer to various metrics, which denote the tool's characteristics such as the operating characteristics, valve positions, gas flow controller status etc. Single chamber Gasonics tool or double chambered Mattson tools were the 2 different types of plasma strippers being used at AMD and the SVID list, provided by the tool manufacturer was readily available.

Standard etherlite terminal boxes: These were necessary to serve as the communication interface between the tool, equipment interface and the FDC server system.

Customized configurable equipment interface communication interface (CEI):

The existence of an equipment interface communication was highly essential to configure the data inputs and data outputs to and from the tool to the various parts of the FDC system. The SECS-GEM standard of communication was used to communicate with the tool.

Triant Modelware software package

The crux of the FDC system is the tool monitoring and analysis software. The Modelware software supplied by Triant was selected to be the FDC software. It was a multivariate model-based software working on the principles of Universal process modeling. The user-friendly Graphic user interfaces (GUIs) helped in efficient real-time analysis.

Dataserver to store data files

The FDC required a huge amount of data to be collected for creating models and analysis purposes. The Dataserver utility, which comes with the Modelware software, was used as the data collector.Silverbox data acquisition boxThe FDC system usually requires a Data acquisition box [9], if any add-on sensor is attached to the tool with the aim of collecting any additional information unavailable from the tool. In the case of the Plasma strippers, it was found that the required parameters were readily available from the SVIDs that the tool was incorporated with by the manufacturer. So, the data acquisition box called Silverbox was not necessary.Additional requirements prescribed by the etch module

The FDC system for most of the modules has a system model in which the FDC module splices between the tool and the EI. Being in between the tool and the EI helps in an efficient, robust and easy mode of data collection and analysis. But this system has its own hazards. There is always a risk on the entire production system to shut down due to any error generated by the FDC system, i.e, even a small error produced by the data collector can shut down the communication between the tool and the equipment interface. This is a highly undesired aspect of such a system.

Upon the insistence of the etch module that the FDC system should not be a hindrance to the production process, a different set-up called the custom dual communications logic server CLS (EI) system was created as shown in Figure 3.1.

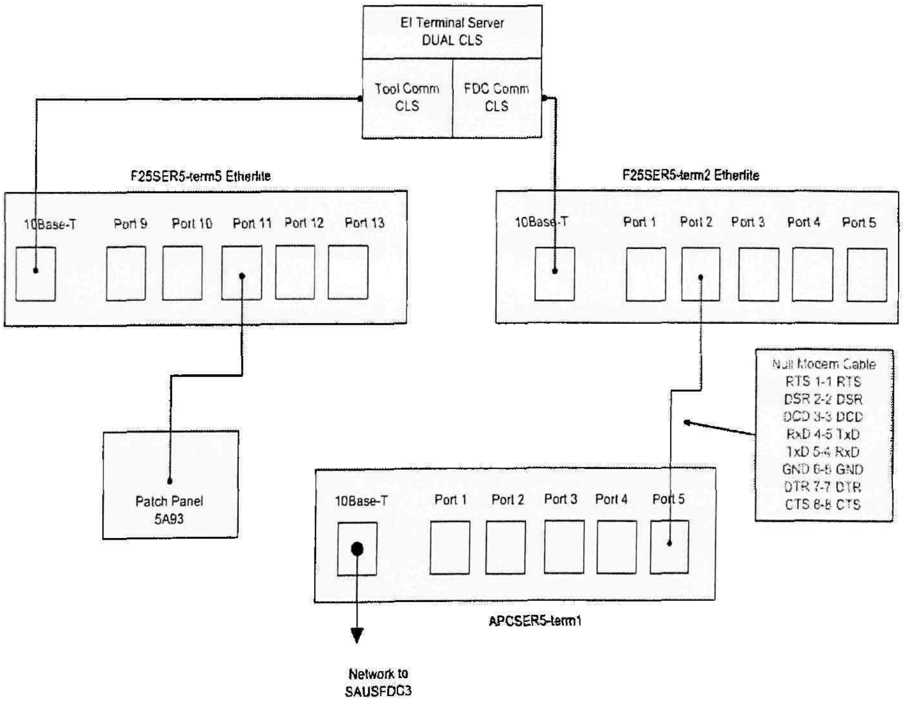

Figure 3.1.Custom dual communications logic server CLS (EI) system [2]

Newly enhanced features of ModelWare [3] 2.8 fault-detection software include an alarm system that detects subtle faults on individual signals and greater off-line data analysis capabilities that can pinpoint alarms occurring during wafer processing. Additional features are quick access to archived data files, improved equipment health summary reports, and improved installation, setup, and configuration components. The model-based alarm automatically identifies processing and equipment faults before the next wafer is loaded, decreasing yield loss. The software also can be configured to automatically stop equipment when a fault is detected.

3.2 Common Faults and issues detected through Fault detection and classification

Although the global aim of FDC is "Automatic tool shutdown Mechanism", wherein the tools gets automatically shutdown immediately upon any undesired change in the tool operating conditions or the recipe conditions. Such faulty instance could be caused through various mechanisms. It could be due to an error by the tool operator or due to the change in the settings on the tool because of a maintenance work or due to the degradation of the tools performance with time. It has been observed that in the case of plasma strippers, the faults have been predominantly caused to the tool's degradation with time. FDC has been one the most dependable system used for the detection of even minor deviations of the tool's performance or the process change. Thus it is widely used for identification of potential faults and for preventive maintenance well before the occurrence of a much more damaging fault. FDC is also useful in making periodic checks on the tool even if there is no inherent fault with the tool's present state. The chamber comparison aspect of FDC helps in efficient maintenance of the tool's performance uniformly under the expected control limits. Some of the important applications of FDC other than automatic tool shutdown and fault detection after the occurrence of the fault are as follows.

3.2.1 Chamber Parameter Comparison

In the following case, it was suspected that the performance of one of the plasma strippers did not match with that of another standard reliable plasma stripper. The Report generator utility of the Modelware software was utilized for data analysis over a certain period of time and the comparison of data using JMP clearly explained the deviation.

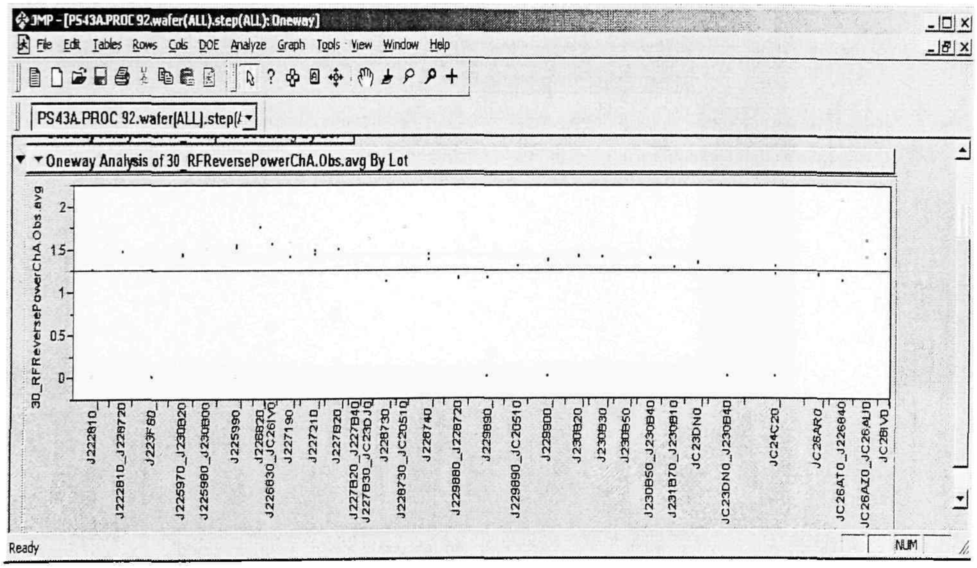

Figure 3.2. One-way analysis of RF reverse power observed on PS43A

The RF reverse power parameter is an important parameter that needs to be under constant check in the case of the plasma strippers. It is responsible for the 'charging issues' on the wafers, which result in die fails during the wafer level reliability test known as WLR test. Hence the RF reverse power is expected to be as low as possible.

In the case of PS43A, a particular process was selected and the data for the RF reverse power corresponding to that lot was collected over a period of time. It was found from Figure 3.2 that the RF reverse power was centered predominantly on 1.25 watts. For the same period of time, PS44A's RF reverse power was collected and compared. It was found that the reverse power was around 3.5 watts as in Figure 3.3.

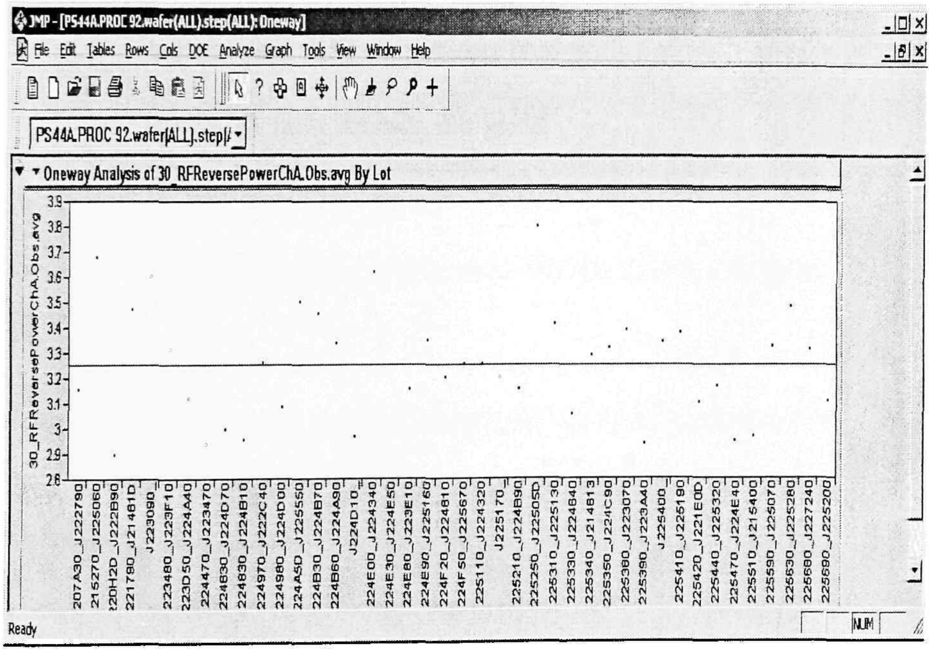

Figure 3.3. One-way analysis of RF reverse power observed on PS44A

The Modelview snapshot of PS43A and PS44A MAF gives an easy understanding about the difference in operators of the tools. The spikes noticed in PS43A have a peak power of about 5 or 6 Watts, which is an acceptable level while the spikes on the PS44A chamber reach even above 10 watts, which definitely is a cause for potential wafer charging effects. Figure 3.4 depicts the deviation and the comparison between the powers of both the chambers.

Although this case did not prove to be a potential faulty case, it has been observed in many other cases that the reflected power was higher than the expected level. Whenever such a deviation is noticed, the tool equipment engineer is notified about the problem. Upon RF tuning and RF matching and checking of the generators, the RF reverse power level is brought back to normal and the issue is resolved well before it causes any alarming impact on the WLR fails, in turn the yield.

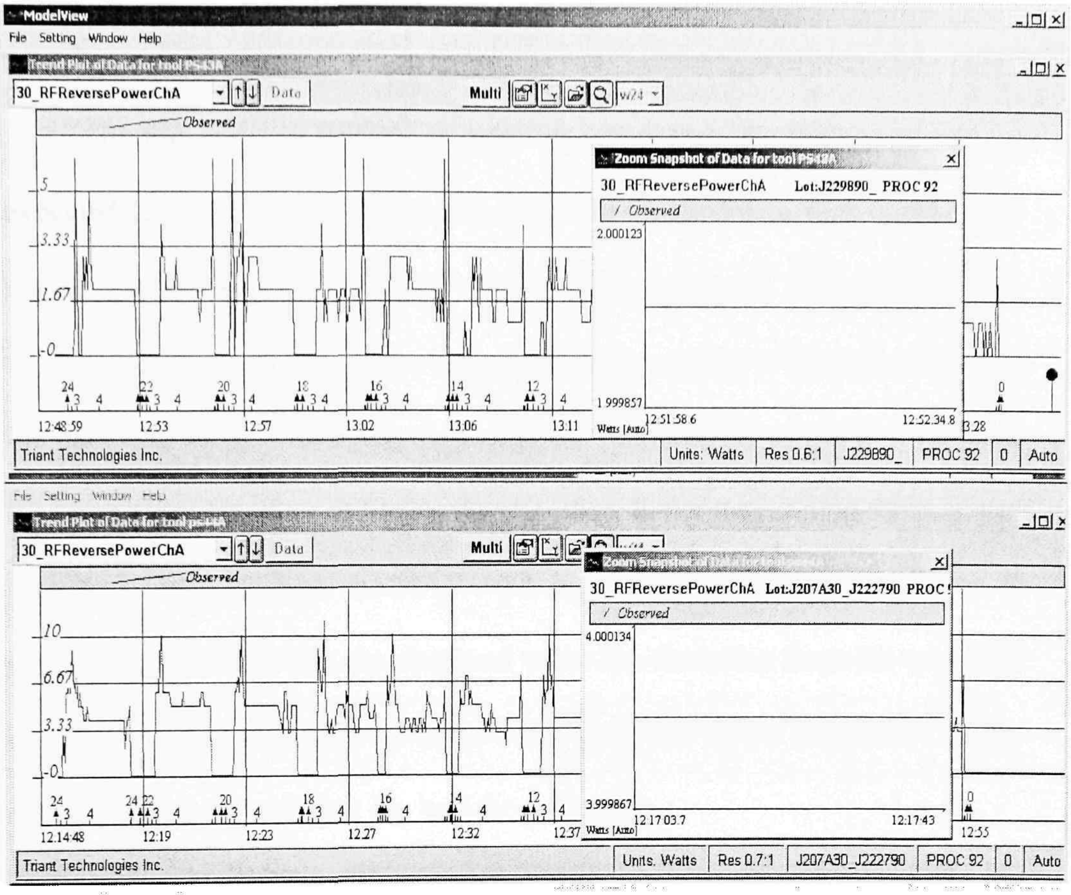

Figure: 3.4 Comparison of RF reverse power between PS43A and PS44A

3.2.2 Recipe specific Negative tool Health observed on PS40A

FDC using the ModelWare mechanism is an efficient tool to gauge the performance of a recipe on a particular tool and the tools reaction to it when compared to other recipes.

The tool health parameter determined by the Modelware software and the standard deviation of the lots tool health is charted in Workstream and is control between certain control limits. Whenever the tool health value goes out of the control limits, an alarm is created in Workstream explaining that there is a potential issue.

In the case of PS40A, it was observed that the tool remained at expected levels for most of the processes but had a dip in tool health only during particular process. Upon careful investigation it was figured that whenever Process 84 ran on the tool, the RF reverse Power level rose beyond the expected value. The equipment engineer was notified of the problem and the issue was taken care of tuning the chambers better for running the process. Figures 3.7 and 3.9 show the MAFs with high ranges of RF Reverse power. It is clearly observable that the observed value has deviation from the expected green band. Whenever the observed value goes out of the model the health chart indicates a significant dip into the red region.

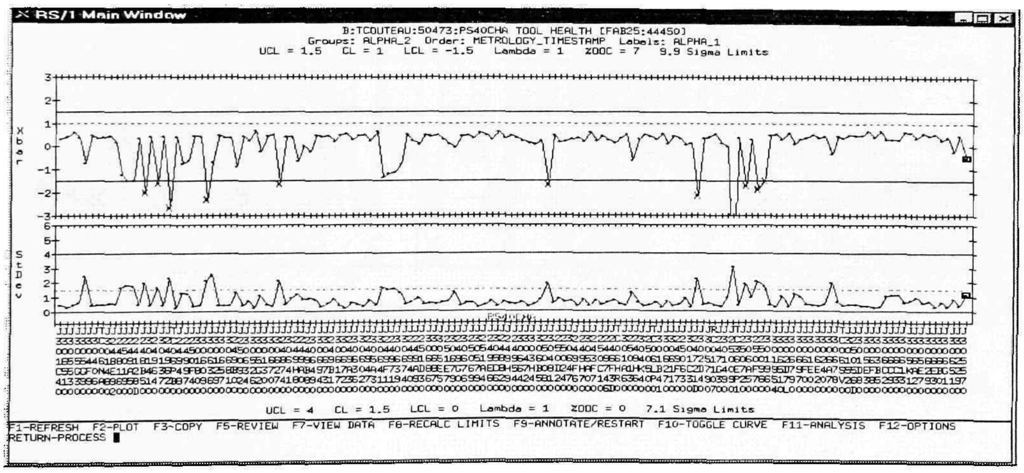

Figure 3.5. Workstream tool health chart indicating a significant dip of the tool health into the red region.

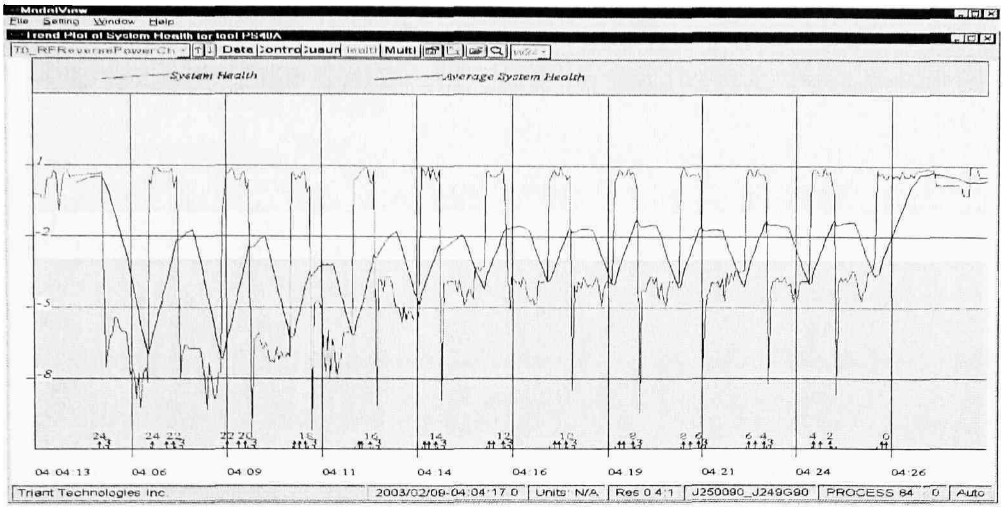

Figure 3.6. Tool Health Modelware chart for a lot running PROCESS 84 recipe

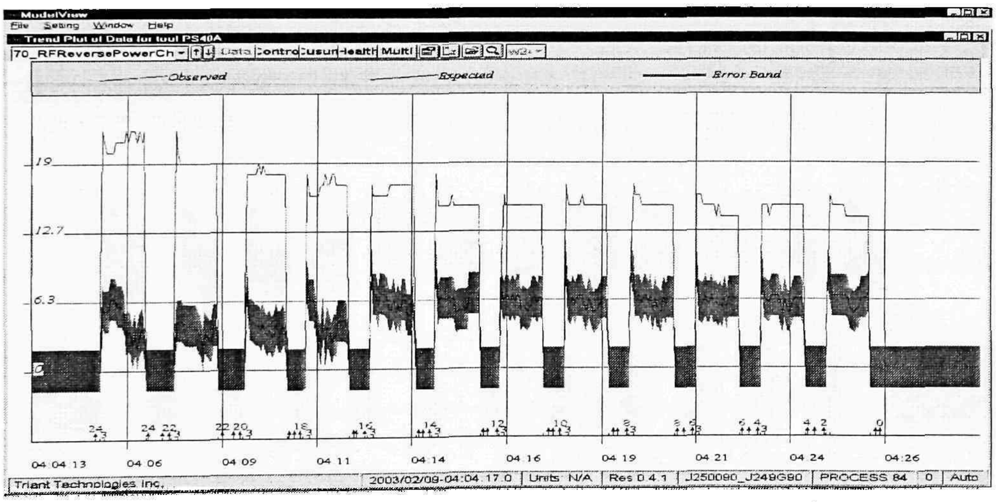

Figure 3.7. RF Reflected power variation observed for the corresponding lot, running PROCESS 84 recipe

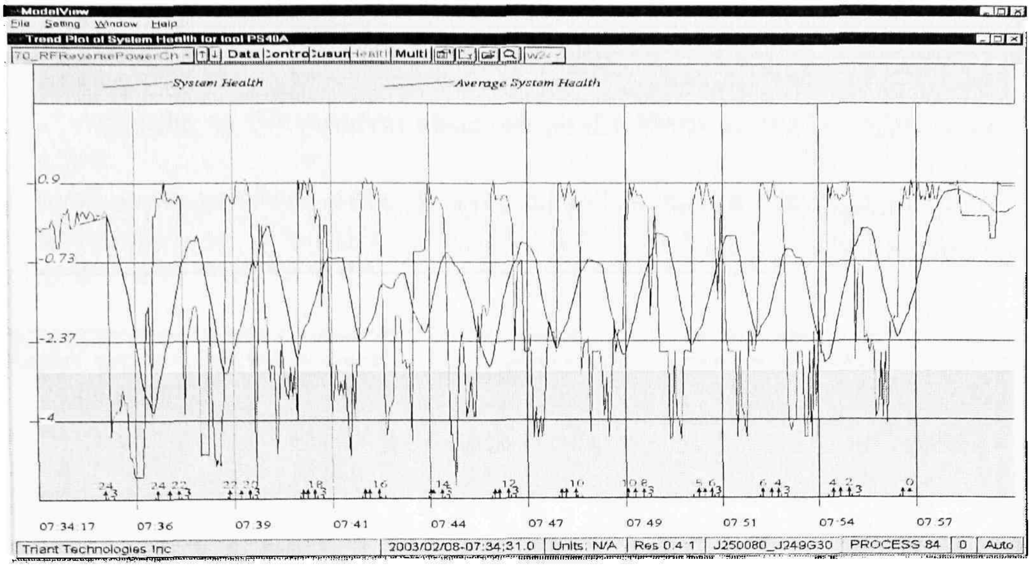

Figure 3.8. Tool Health Modelware chart for a lot running PROCESS 84 recipe

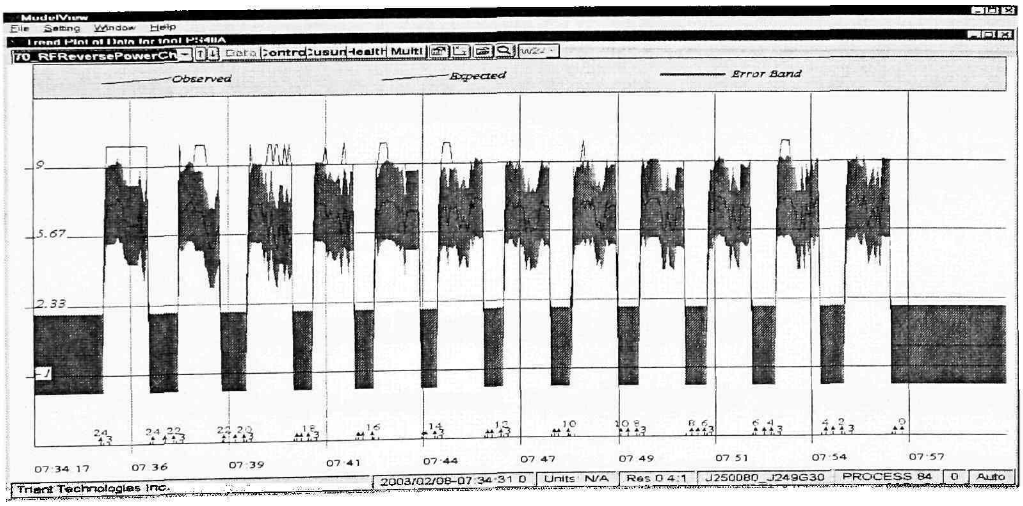

Figure: 3.9 RF Reflected power variation observed for the corresponding lot, running PROCESS 84 recipe

3.2.3 Gasonics PS20 RF-Reflected power shift

Similar to the problem observed on the Mattson Plasma strippers, RF reverse power problems were observed on a Gasonics tool. In Figure 3.10, it is clearly visible that the tool had an erratic operating range.

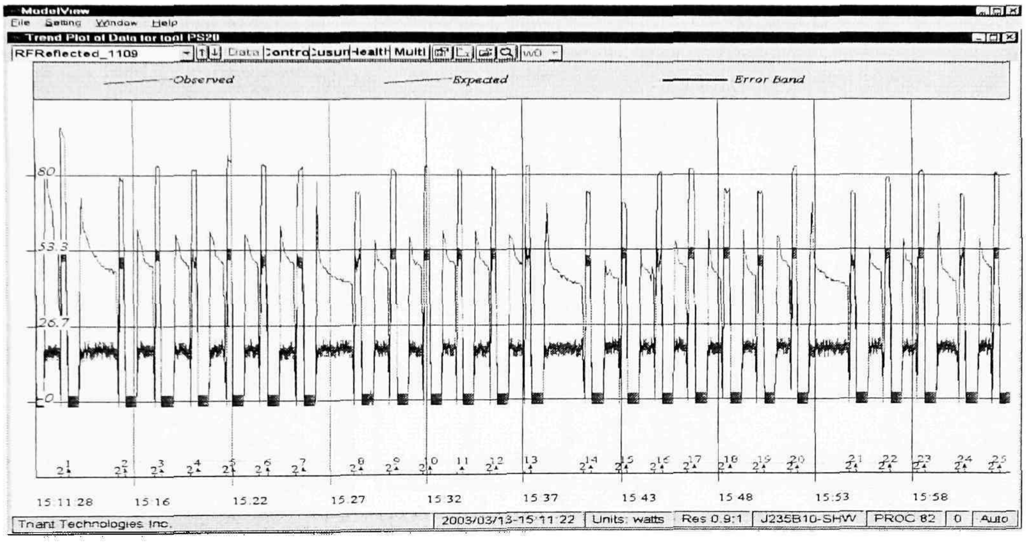

Figure 3.10. Tool Health Modelware chart for a lot running PROCESS 84 recipe on a Gasonics single chamber tool

3.2.3 Gas Flow/Recipe Errors Detected Using Modelware

One of the unique occurrences, yet, an important issue observed with the help of FDC-Modelware software, was a rare case of a recipe error. This instance occurred due to the error committed by the user while keying in the recipe on to the tool. It could be observed from Figure 3.11 that Gas 1, Gas 2, and Gas 3 have flows during the processing of a lot. It was apparently found that the Spec for the recipe did not have any Gas 3 flow for that process. The Figure 3.12 shows the expected gas flow representation of the recipe.

This problem was noticed within a short period of time and it was ensured that this isolated incident of a mistyped recipe did not cause a loss of a number of lots as scrap.

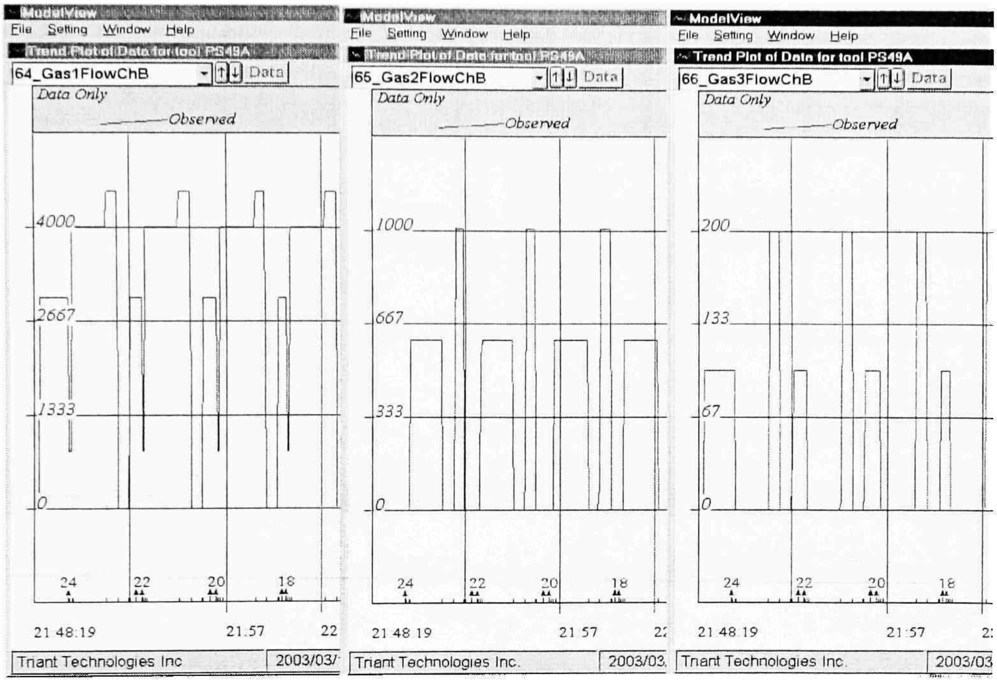

Figure 3.11. Representation of the three gas flow values of a lot with erroneous Gas 3 flow values

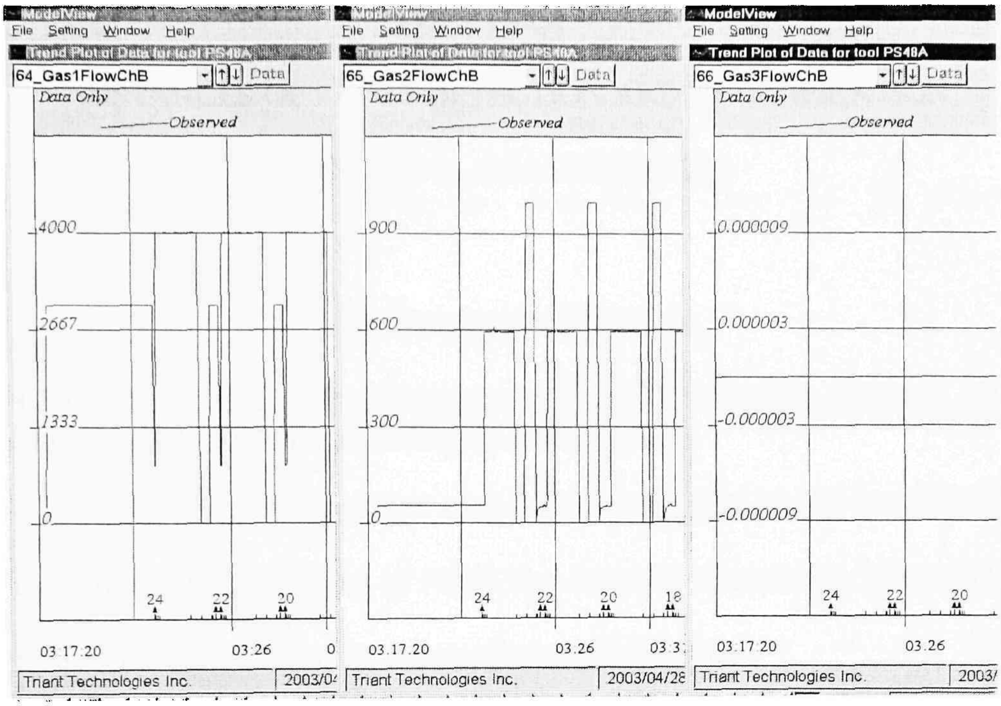

Figure3.12. Representation of the three gas flow values of a lot with no Gas 3 flow

CHAPTER 4

INSTANCES OF FAULT DETECTION AND CLASSIFICATION ON THE PLASMA STRIPPERS

4.1 Temperature Deviations

4.1.1 Case 1: The Platen Temperature Signal Abnormality Detected on a Mattson plasma Stripper due to faulty heater element.

The ModelWare system successfully detected a change in the platen temperature on chamber A of PS44. The data was immediately presented to the module to determine the cause of the sudden variation.

The multivariate system was able to determine the variation immediately on June 2, 2002. The first lot, which showed the variations, was J218310 of the recipe HIGH DOSE N2. Subsequently, many lots belonging to the same recipe showed the deviations.

Without the use of the trace data, it would have been very difficult to determine the variation and its cause. The variation in the temperature was found to be around 5% above the normal value, which could be significant to the process.

The Tool Health (TH), which is the output of the multivariate analysis, reacted accordingly as the temperature varied. The fact that the tool health decreased by around 150% below the baseline with the increase of around 5% of the temperature parameter stands testimony to the sensitivity and reliability of the model.

The FDC successfully detected the abnormality immediately as it occurred. Upon investigation, it was found that the deviation was due to faulty heater elements. Upon replacing the heater elements and calibrating the Watlow temperature controller, the temperature came back to normal operating conditions.

Summary

Tool Health (TH) models for PS44 (chambers A & B) were created in March 2002, based on a series of tool parameters defined by the Etch module. Key tool parameters such as the RF power, process pressure, gas flows, platen temperature, etc. were incorporated in the model. The processes were continuously monitored and the models were periodically updated to conform to the latest changes in the operational procedures, recipes, and parameter values.

This report elucidates the use of a multivariate FDC system in detecting early failure signals in the platen temperature parameter of chamber A of plasma stripper PS44. The variations observed on a particular recipe, HIGH DOSE N2 have been highlighted here although other recipes such as PROCESS 84 and EPD O2 ASH (30 SEC OE) also show signs of change in temperature signature.

Figure 4.1 shows the temperature setting under normal operating conditions for the HIGH DOSE N2 recipe. It may be noticed that the peak temperature is around 253°C and the observed temperature curve, which is conformal with the expected temperature curve lies within the green error band determined by the model.

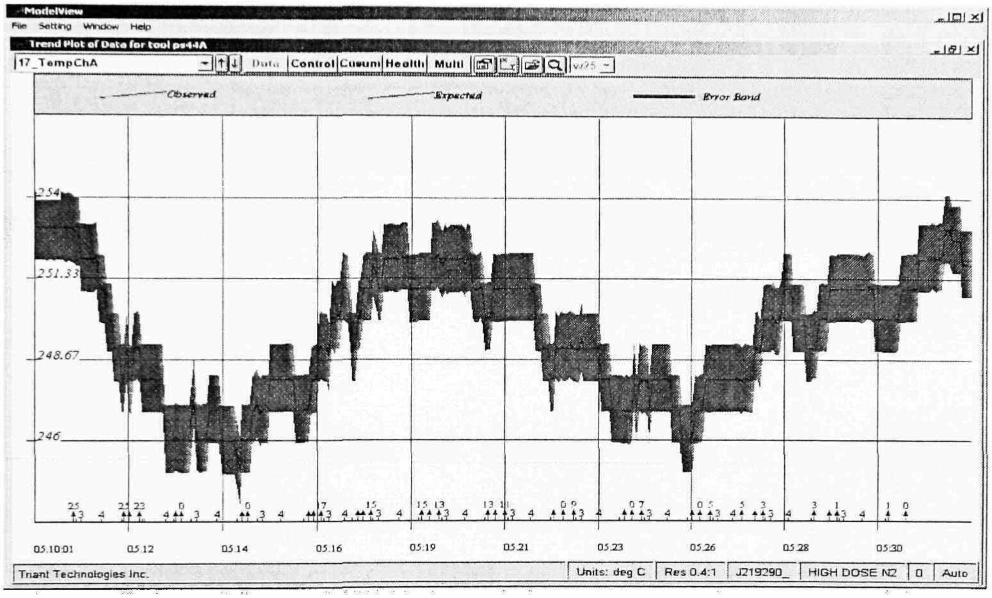

Figure 4.1. Temperature trend observed under normal operating conditions.

Figure 4.2 shows the tool health chart. It is divided into the green, yellow and red region indicating the normal state, the warning alarm state, and the critical fault halt state, respectively. The tool health, in this case, is around 0.7. This is in the normal state indicated by the green region.

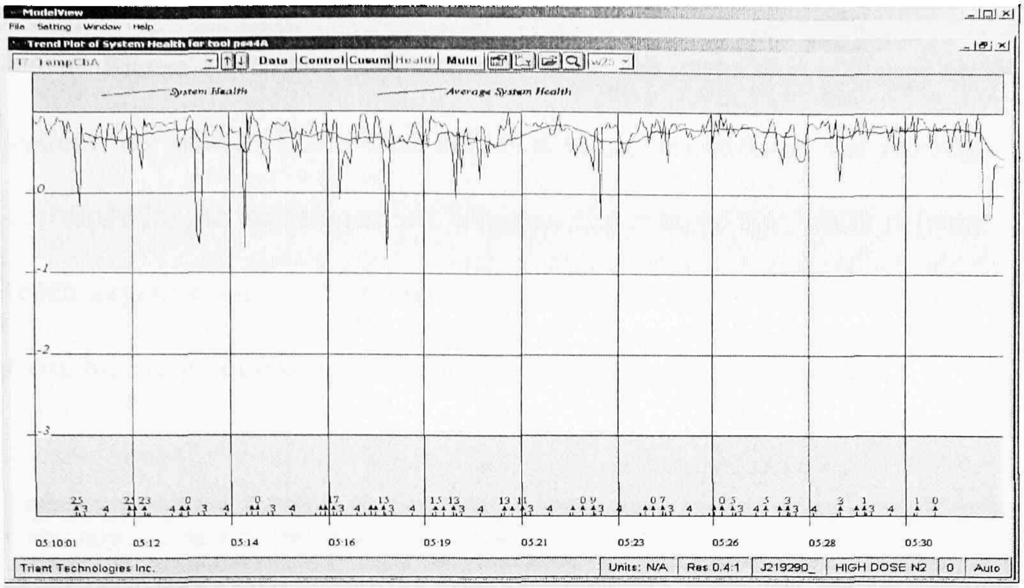

Figure 4.2.Tool health observed under normal operating conditions.

Figure 4.3 illustrates the observed change in the temperature characteristics using the Model Ware system. There is a deviation of about 10-15 °C from the normal operating conditions, which is around 5% above the expected range.

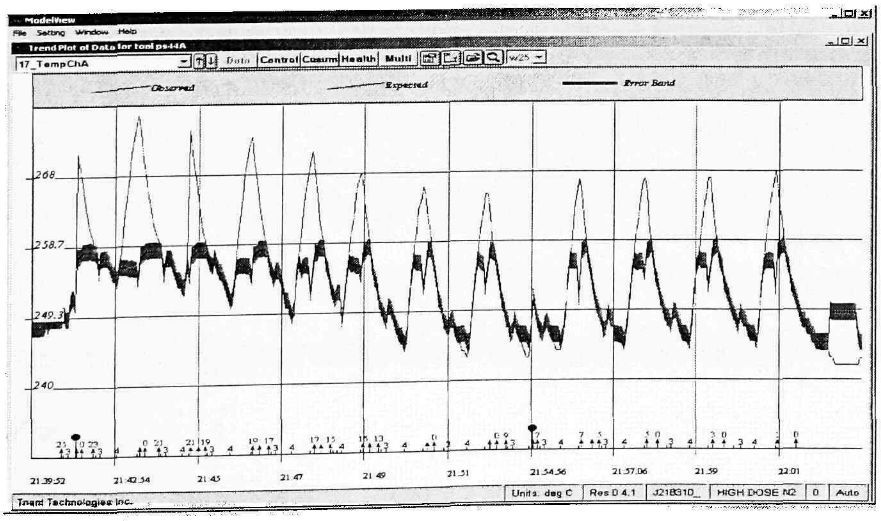

Figure 4.3.Observed change in the platen temperature trend.

Figure 4.4 clearly demonstrates the impact of the above change on the system tool health. The system health is found to spike into the red region, corresponding to the temperature changes. The average tool health is found to reach negative values of around – 4. Subsequent to this lot, this poor health trend has been noticed in several lots belonging to different recipes.

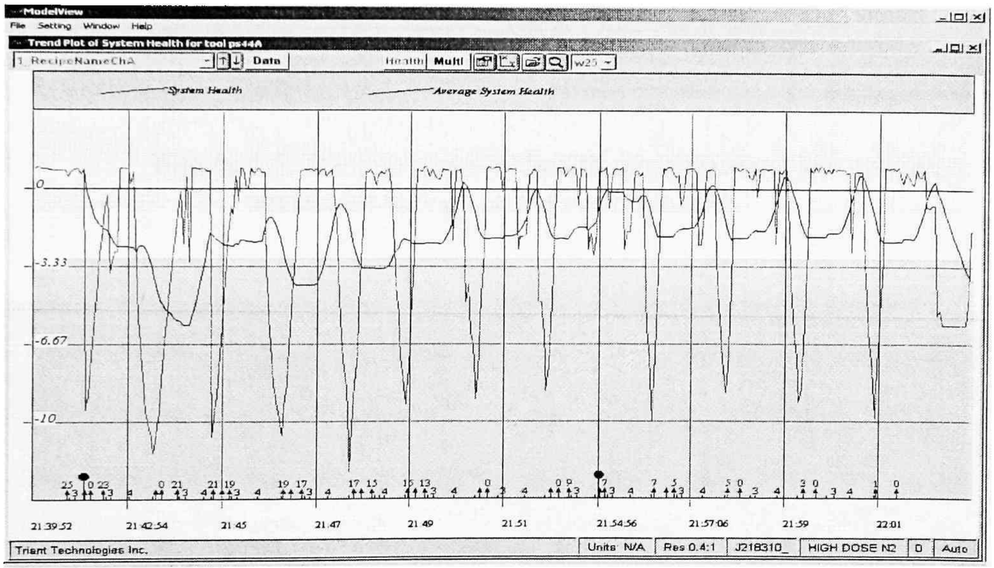

Figure 4.4.Poor Tool health observed due to the change in temperature.

Figure 4.5 depicts the Workstream tool health chart showing the sudden undesired change in the system health. The comment column shows the action that was taken to rectify the problem, which in this case was replacement of faulty heater elements and calibrating the Watlow temperature controller.

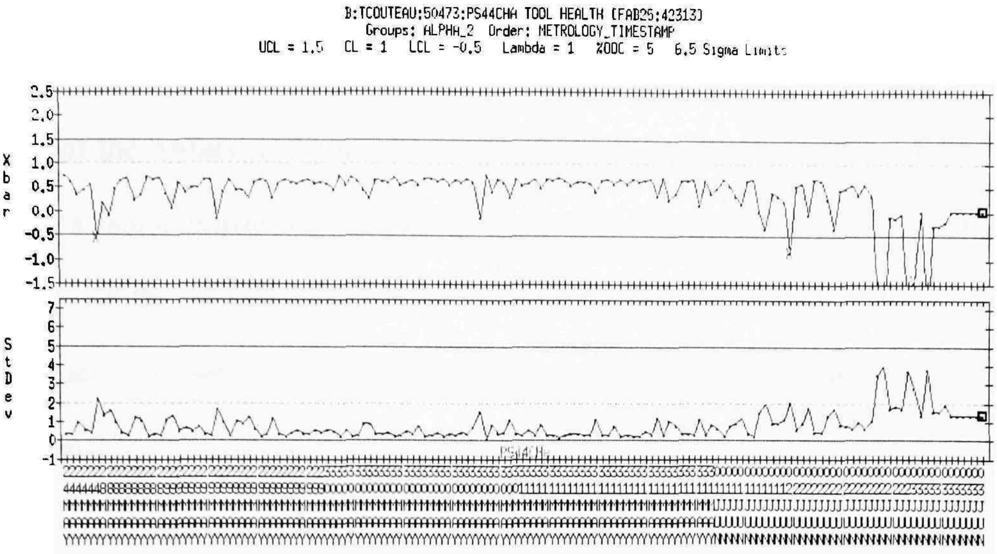

Figure 4.5. Workstream tool health chart showing the sudden undesired change in the system health.

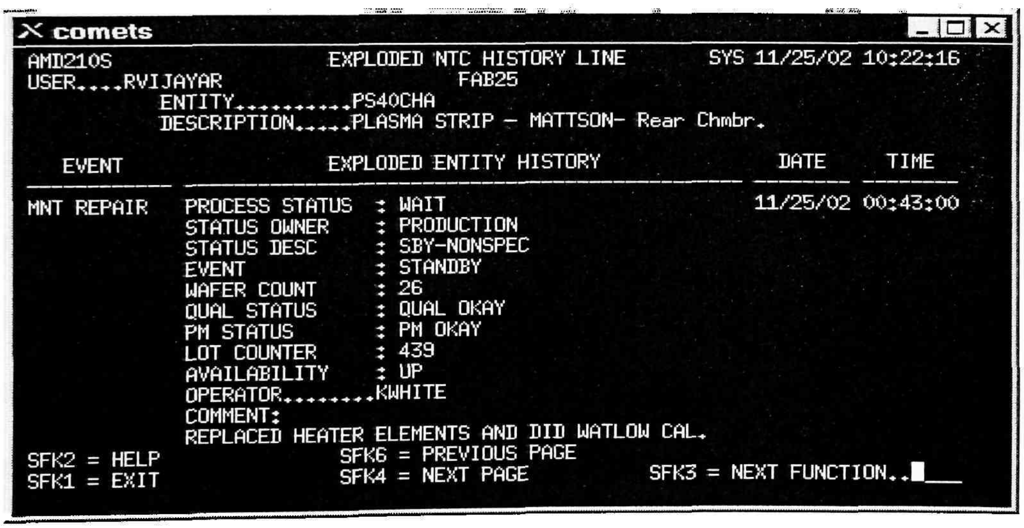

Figure 4.6. Comment window showing the action that was taken to rectify the problem

Conclusion

The ModelWare system was successful in early detection of a tool parameter abnormality. Temperature is an important parameter in the plasma strip process and had it been out of spec. limits for a long period of time, it would have had impact on the stripping process and in turn the defects and yield of the wafers in the lot. Even though this instance of deviation did not cause a major impact on the tool or the wafers, it clearly demonstrated the ability of the ModelWare system to detect even the slightest change in operating parameters. This helped in identifying the deviating parameter and the cause for the deviation. Necessary steps were taken to put the tool back into normal processing limits.

4.1.2 Case 2: Temperature Deviation Detected On A Plasma Stripper Due To Faulty Eurotherm Temperature Setting

The ModelWare system successfully detected a change in the platen temperature on chamber A of PS44. The data was presented to the etch module to determine the cause of the sudden variation and steps were taken to rectify it. The etch module acknowledged the detection of the fault by Modelware as very timely and useful. The multivariate system was able to determine the variation immediately on September 20, 2002. The first lot, which showed the variations, was J232280 of the recipe PROCESS 82. Subsequently many lots belonging to different recipes showed temperature excursions.

Without the use of the trace data, it would have been very difficult to determine the variation and its cause. The variation in the temperature was found to be around 3 to 4% below the normal value, which could be significant to the process. The Tool Health (TH), which is the output of the multivariate analysis, reacted accordingly as the temperature varied. The fact that the tool health decreased to around -8 with the decrease of around 4% of the temperature parameter stands testimony to the sensitivity and reliability of the model.

The FDC successfully detected the abnormality immediately as it occurred. Had the temperature change not been detected as early as it had been, it might have had adverse effects on the wafers. Upon investigation, it was found that the eurotherm setting, that controls the temperature on the Mattson tool chamber, had changed from the normal operating limits. Once the setting was calibrated to proper limits, the tool came back to normal operation with no instances of any temperature deviation.

Summary

Tool Health (TH) models for PS44 (chambers A & B) were created in March 2002, based on a series of tool parameters defined by the Etch module. Key tool parameters such as the RF power, process pressure, gas flows, platen temperature etc. were incorporated in the model. The processes are continuously monitored and the models are periodically updated to confirm with the latest changes in the operational procedures, recipes and parameter values.

This report elucidates the use of a multivariate FDC system in detecting early failure signals in the platen temperature parameter of chamber

A of plasma stripper PS44. The variations in temperature signature observed on the recipes such as PROCESS 82, PROCESS 84 and EPD O2 ASH (30 SEC OE) have been highlighted.

Figures 4.7 and 4.9 illustrate the change in the temperature characteristics observed using the Model Ware system, on lots running the recipes PROCESS 82 and PROCESS 84, respectively. It may be noticed that there is a deviation of about 10 °C from the normal operating conditions, which is around 4% below the expected range.

Figures 4.8 & 4.10 clearly demonstrate the impact of the above changes on the system tool health of the corresponding recipes. The system tool health is found to spike into the red region, corresponding to the temperature changes and the average tool health is found to reach negative values of around – 8.

Comments from Etch Module

A strip rate test is done every 24 hrs, in which the first wafer from a lot is inspected for faults. Even this test could not have caught the temperature excursion on PS44-A as the temperature excursion is predominantly seen after a couple of wafers and the first wafer would have been good. The next possibility of detection might have been only after 3 or 4 days down the stream, during defectivity analysis.

The Modelware system was successful in early detection of a tool parameter abnormality. This parameter could have gone undetected for a great period of time and could have had adverse effects resulting in wafer scrap and tool downtime. The etch module felt that this instance of efficient fault detection proves to be an excellent justification for the request of FDC implementation on all Plasma strippers and other toolsets using the Modelware based technique.

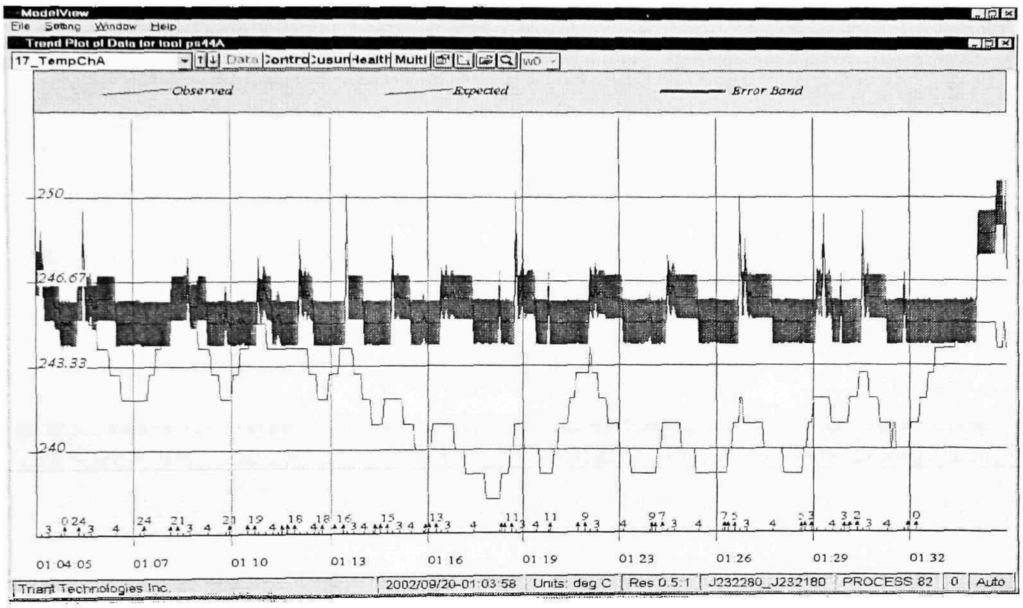

Figure 4.7 Temperature change noticed in PS44A for a lot running recipe PROCESS 82.

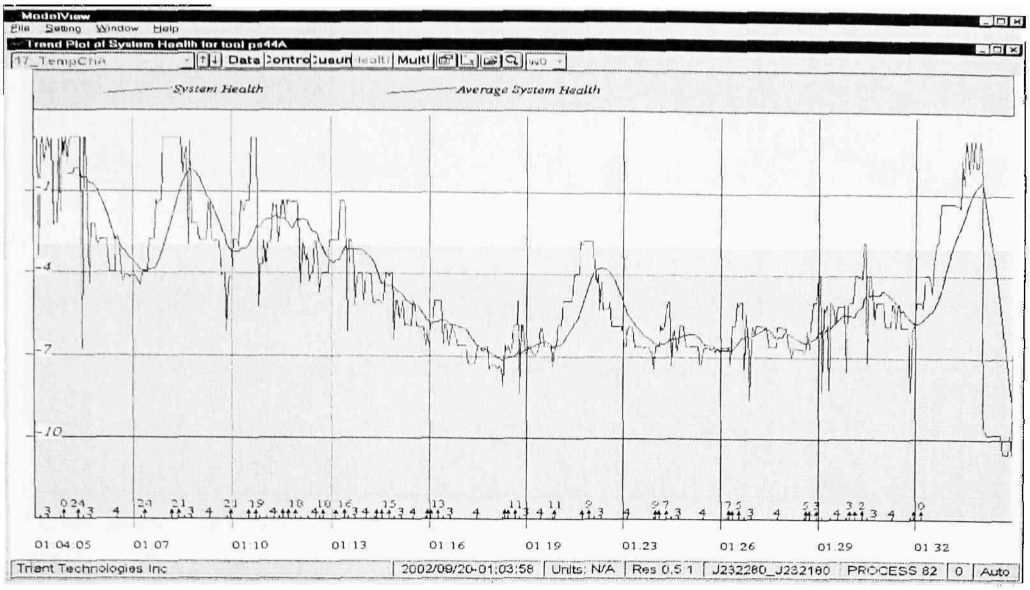

Figure 4.8. Tool Health change observed for the corresponding lot, running PROCESS 82 recipe.

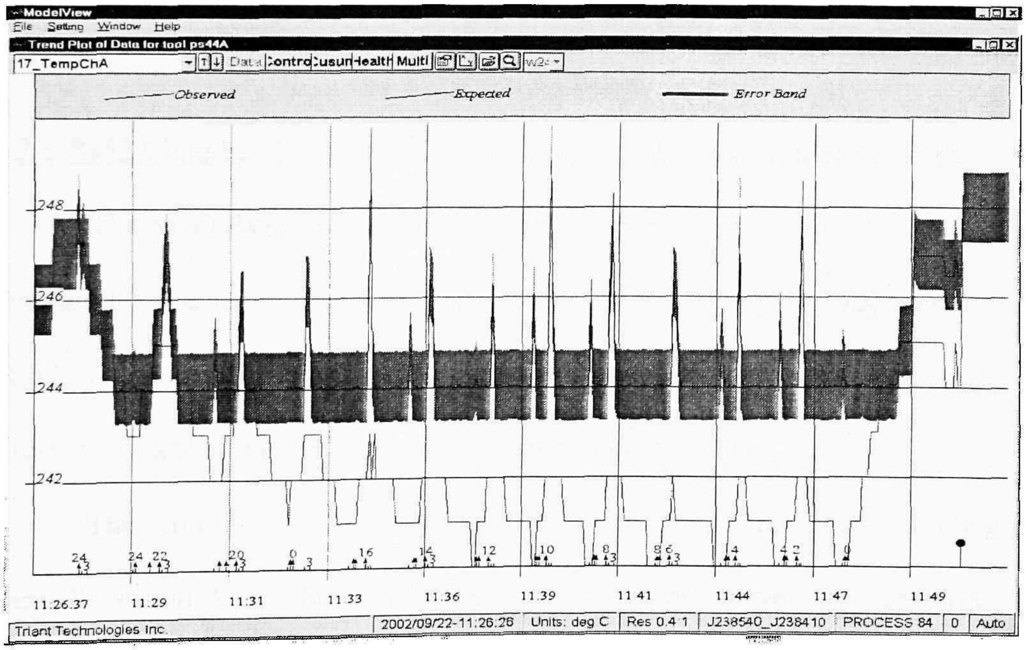

Figure 4.9. Temperature change noticed in PS44A for a lot running recipe PROCESS 84.

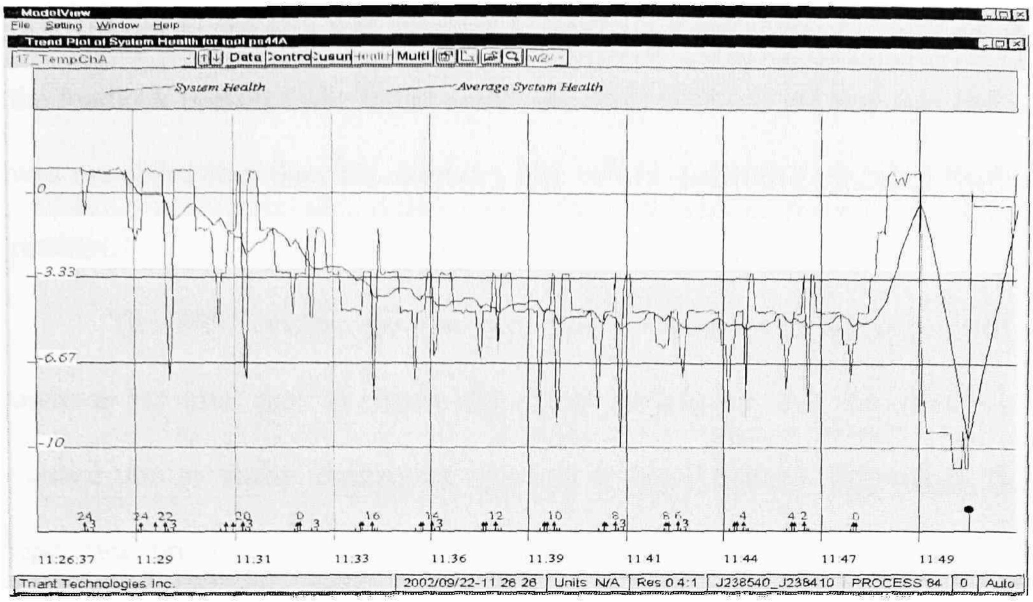

Figure 4.10. Tool Health change observed for the corresponding lot, running PROCESS 84 recipe.

4.2 Pressure Deviation

4.2.1 PS52 Chamber-B Pressure Deviation Detected Using Modelware FDC

The ModelWare system successfully detected a change in the loadlock pressure trend and simultaneously, a process pressure change on chamber B of PS52. The data was immediately presented to the etch module equipment engineer to determine the cause of the sudden variation.

The multivariate system was able to determine the variation immediately on April 10th, 2003. The first lot, which showed the variations, was J314760 of the recipe PROC 85. Subsequently, many lots belonging to the same recipe showed the deviations.

Without the use of the trace data, it would have been very difficult to determine the variation and its cause. In fact, the Workstream comment for the misbehavior of the tool was assigned to faulty EI issues. But, the variation in the loadlock pressure was found to be very obvious from the trace data and it was one third less than the normal value, which could be significant to the process.

The FDC system was not only able to detect this fault in a timely manner but also able to negate the earlier assumption that this fault was caused due to faulty Equipment interface issues. Loadlock determines the operating pressure of the plasma strippers. Had the loadlock pressure and chamber pressure change not been detected as early as it was, it might have had irreparable effect on the wafers.

4.2.2 Summary

Since PS52 was a new addition to the already existing set of plasma strippers, it did not have models built for this particular recipe – Process 85. But the trace data itself made it quite obvious about the change in trend of the pressure parameters. In order to clearly portray the deviation of the parameters, a model was built after the fault had occurred and the failed lots were validated. Key tool parameters such as the RF power, process pressure, gas flows, platen temperature, etc., were incorporated in the model.

This report elucidates the use of a multivariate FDC system in detecting early failure signals in the loadlock pressure and process pressure parameter of chamber B of plasma stripper PS52. The variations observed on a particular recipe, PROCESS 85 have been highlighted here.

Figure 4.11 shows both the loadlock and chamber pressure setting under normal operating conditions for the Process 85 recipe. It may be noticed that the loadlock pressure is between 2.7 to 3.16 torr and the chamber pressure stays at 3 torr, 0.8 torr, 1.1 torr and 3 torr at steps 1, 2, 3 and 4, respectively.

Figure 4.12 illustrates the observed change in the loadlock pressure characteristics using the Model Ware system.

Figure 4.13 illustrates the observed change in the chamber pressure characteristics using the Model Ware system.

Figure 4.14 clearly demonstrates the impact of the above change on the system tool health. The system health is found to spike into the red region, corresponding to the temperature changes and the average tool health is found to reach negative values of around – 10. Subsequent to this lot, this poor health trend has been noticed in few more lots belonging to the same recipe.

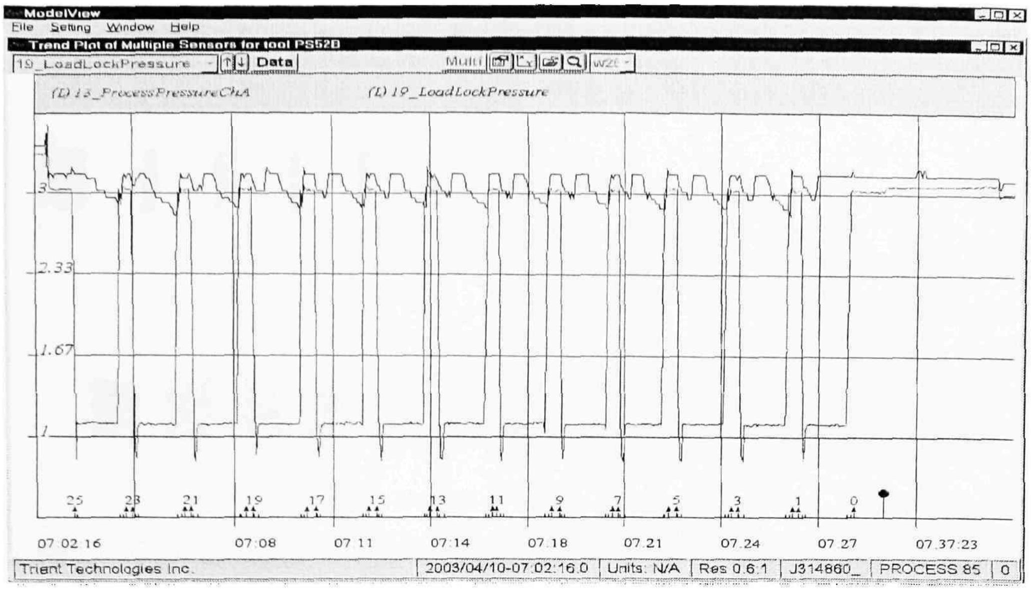

Figure 4.11. Loadlock pressure and chamber pressure trend under normal operating conditions.

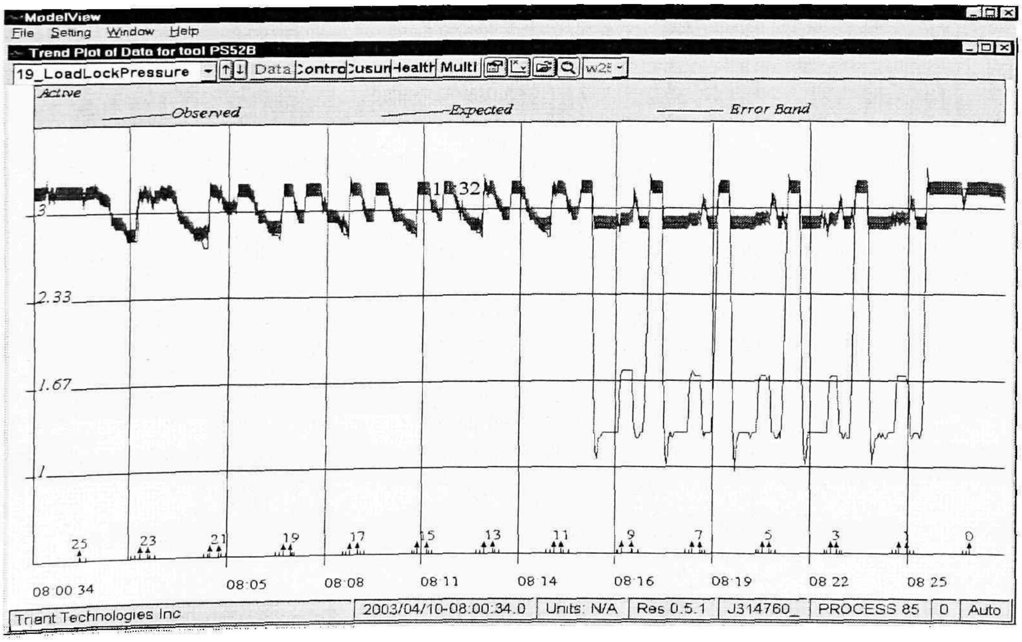

Figure 4.12. Observed change in the loadlock pressure characteristics

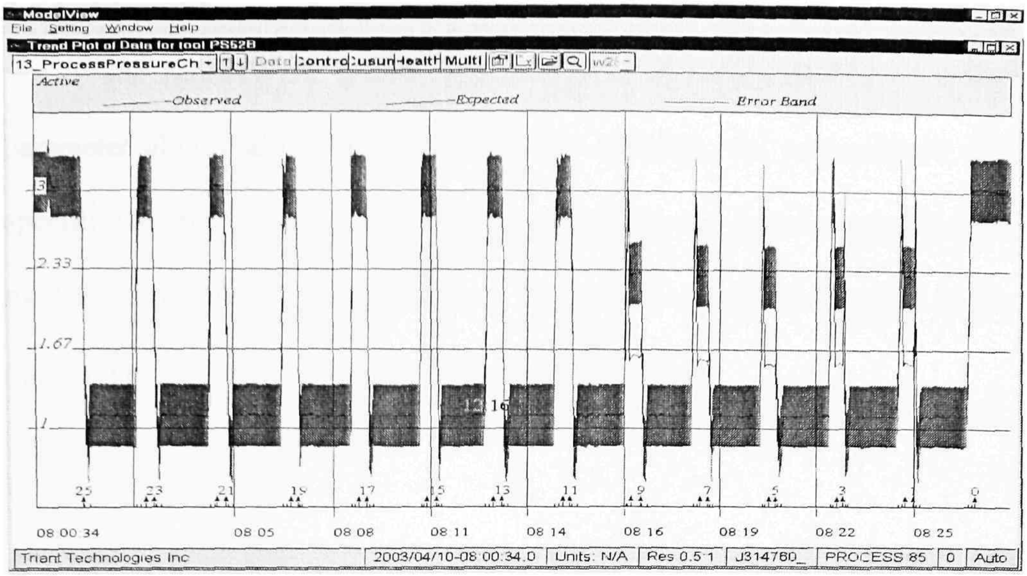

Figure 4.13. Observed Change in the Chamber pressure characteristics.

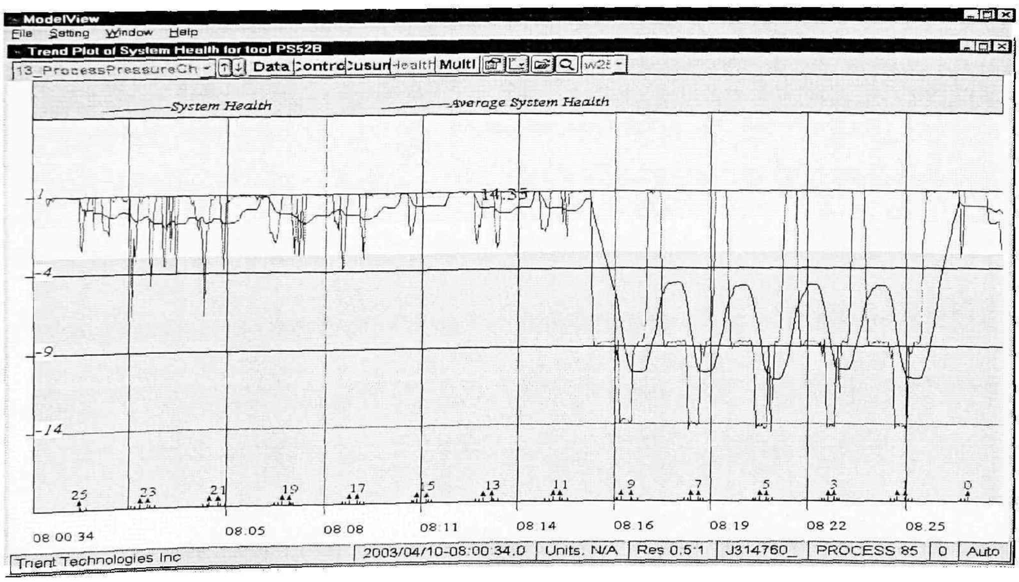

Figure 4.14. Effect of the pressure changes on the Tool health.

4.2.3 Conclusion

The ModelWare system was successful in early detection of a tool parameter abnormality. From this instance onwards, the processes on that specific tool were continuously monitored closely for a few weeks and the models were periodically updated to conform to the latest changes in the operational procedures, recipes, and parameter values.

CHAPTER 5

FUTURE ENHANCEMENTS

5.1 Continuous FDC improvement

5.1.1 Automatic tool shutdown and its implications [10]

Once the basic operating mechanism of the FDC system on the Plasma strippers was well understood and upon reaching the required confidence level on the robustness of the Modelware based fault detection, it was decided to roll out the automatic tool shutdown mechanism. The automatic tool shutdown mechanism needs a highly efficient FDC system devoid of any false alarms. It puts the tool down whenever the tool health goes out of the expected range. The tool cannot be run upon such an occurrence until the issue is addressed and the tool passes the tool health. The potential problem noticed in such a system is the instance of a fault occurring during the night shifts and the tool staying idle for a long time waiting for the issue to be addressed. To mitigate the instances of false alarms, some business rules were agreed upon and it was decided that the automatic tool shutdown would occur whenever there was an instance of 3 continuously failing lots. This kind of an approach helps in avoiding the shutdown to be caused due to one single recipe, which has a bad model, i.e., which does not have enough MAFs in the reference table for that particular recipe. Such a case of a recipe without a perfect model representing its operating condition might result in the FDC software ascribing the tool of faulty operation even when the tool is operating under expected conditions.

Upon the implement of a robust "automatic tool shutdown mechanism" on PS44, it was observed that the tool required lesser number of checks and tool down time for finding faults if any, came down significantly This is because, the FDC system was continuously monitoring the tool for any kind of deviation and reported even the slightest of deviations observed.

5.1.2 Global Model creation/Maintenance

The most important aspect of the FDC system is the creation of robust, strong models for each recipe running on every chamber of the tool. Models are built using the Modelmaker utility of the Modelware software.

Model making procedure involves the identification of ModelWare archived files, which represent the process in its exact working conditions. The files pertaining to each recipe from each chamber is analyzed and only those, which adhere to the values in the spec., are selected and added to the reference table. The Modelware software uses it patented UPM algorithm to come up with a multivariate model based on the reference table data. Once the model gets built, it is validated with some MAFs to test the efficiency of the model. If it is found that a validated MAF has a negative tool health even though it has an acceptable operating procedure, that MAF is added to the reference thereby widening the Model's control limits.

Initially, when FDC implementation was started on the Plasma strippers, only 3 or 4 tools were identified as the tools requiring FDC. Hence the creation of Models was fairly easy, as a maximum of around 20 models were needed for each tool. But as the FDC mechanism was extended to around 19 plasma strippers, the model creation and maintenance became cumbersome. It required an engineer dedicated solely for the purpose of looking into the Modelware Workstream tool health charts; identify the faulty lots and their corresponding processes. Then that particular process was remodeled in case the operating conditions changed and yet, was under agreeable limits.

In order to tackle the problem of the time consuming process of Model making and maintenance, it was proposed to Triant to have a single global model for each recipe catering to all the tools. For example, Process 84 on the entire chamber A series was expected to have the same operating conditions. The single global model would have MAFs from all the tools in the reference set, thereby creating a widened band for the operating conditions in the model. This aided in the easy and effective maintenance and creation of models. Such a system ensured that there were only around 30 models for the entire Plasma stripper toolset, which was a significant decrease from around 400 individual tool/recipe based models. It was also useful in effective chamber comparison, which made sure that there was not any significant deviation in the operating conditions of one chamber of a tool with respect to the others. Such an implementation had a drawback though. It decreased the efficiency of the model to catch minor deviations. Although the process conditions on all the tools were expected to be the same, it was well understood that the tools themselves were not uniform in their functioning. Some of them were old while the others where new, which in turn meant that some of the parts of the tools were older and caused the tool to behave differently.

When MAFS pertaining to all the tools were added to the reference table to create a global Model, the limits of operation of each parameter was expanded and hence the occurrence of a fault due to minor deviations got eliminated. A trade off was accepted in the easy creation and maintenance of the models to that of the model's ability to catch small deviations.

5.1.3 Identification and addition of extra SVIDs for better process control

The FDC system can be utilized to the fullest potential if its data collecting and parameter analysis mechanism is used to collect as much information as possible pertaining to the process. Hence the identification of extra SVIDs, which would give a better picture about the process, is necessary. This can be done by analyzing the faults that have occurred in the past and by identifying any available SVID, which is either a contributor to the fault or an eliminator of the fault. For example, in the case of the plasma strippers, there were a number of "lift pin" speed errors. The vendor was requested for a special set of SVID values that could return a value for the speed of the lift pins and this helped to eliminate the subsequent errors.

.1.4 Increase in the data collection rate and exploring other faster /efficient ata collection mechanisms.

.nother important aspect that adds value to the FDC system other than the olume of data collected, is the rate at which data is collected. The initial FDC ystems were built with a data collection rate of about 5 seconds i.e., every 5 econds, the data collector polled for data from the tool. The problem ssociated with such a system was that there were many recipes, which had teps smaller than 5 seconds. This kind of data collection approach implied hat there was a possibility of some steps being unnoticed by the data :ollection system and hence, there was a possibility of misrepresentation of he process data. Therefore, it was imperative that the rate of data collection vas on the order of 1-second intervals. The addition of the SXML based data :ollection system helped to bring down the data collection interval. ;ignificant efforts are taken by the FDC system to increase the rate of data :ollection for better real-time representation of process data.

;.1.5 Wafer level fdc mechanism as opposed to the current lot level FDC

Although FDC at a lot-based level [11] is an efficient medium to educe the number scrapping lots, some of the toolset engineers prefer to go to he next level of fault detection, which is wafer level fault detection. In this ıpproach, it is expected that the abnormalities were caught much earlier than he lot-based approach. A significant increase in the yield can be obtained hrough this method because the number of wafers being scraped gets onsiderably reduced due to early wafer level detection of abnormalities. This mechanism adds much more complexity to the data collection and analysis. Currently, APC is working on introducing wafer-level FDC.

5.1.6 Propagation of the FDC mechanism on to other toolsets

FDC mechanism on the plasma strippers proved to be a highly important tool for the process engineer to maintain a tight control in the process and to detect any deviation from the normal. The success of such a system has paved its way for other toolsets in etch to adopt the same FDC approach. Significant work was done to propagate the mechanism on to other toolsets such as the nitride etchers, oxide etchers and polysilicon etchers. All projects required the same approach that was necessary for the plasma strippers, namely identification of potential faults, availability of SVIDs, conducting DOEs to understand the correlation of parameters with the process, and finally, setting up of the data collection and data analysis mechanism.

5.1.7 Correlation of FDC and run-2-run mechanism for effective advance process control.

Even though FDC and run–2-run systems came under the advanced process control mechanism, it was found that there was significant gaps their operating mechanisms. The FDC system and the run-2-run system did not seem to depend on each other for their working, although in many tools, both were in place and they catered towards the same goal of reducing the scrap and increasing the yield.

Keeping this in mind, it was decided to explore the possibility of linking the FDC and run-2-run system and correlate the data obtained from both the systems. It was found that the predictions made by the FDC system and the history of faults occurring on a particular tool /chamber could be highly useful for the design of a run-run controller. The feedback parameter in a run-2-run controller could be decided based on the prior faults and deviations observed in the reports generated through the FDC mechanism. Steps are being taken to effectively analyze data for a period of time on a tool, which has both the mechanisms in place.

5.2 Conclusion

In today's semiconductor manufacturing environment, Advanced Process Control (APC) has become the technology that all companies are striving to understand, obtain, deploy and derive value from. In particular, Fault Detection and Classification (FDC) has become a hot topic of discussion at symposiums, trade shows, in industry journals and of course at the end user or factory level.

Fault Detection is a critical component for management of scrap at all front-end processes, especially lithography and etch. Most fault detection systems are purchased from commercial vendors and customized to match the data collection requirements of the individual factories.

From the practical experiences illustrated in this report, it is clearly seen that advanced FDC implementation is responsible for prominent improvement on the equipment efficiency, tool down time reduction, and equipment utilization rate. It also provides more information and data for equipment troubleshooting, process matching, process data historical trace, and equipment parts lifetime, etc.

Many semiconductor manufacturers, including AMD still have an enormous base of manufacturing facilities, which are still being run by unsophisticated, or primitive control mechanisms. Competitive pressures will not allow any company to ignore the significant efficiencies possible through adopting modern process control technologies. As AMD plans to move into the 300 mm manufacturing segment, there is no doubt that APC would be an integral part of it [12].

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