INFICON

TECHNICAL NOTE

Statistical Process Control with FabGuard®

FabGuard Sensor Integration and Analysis System is a fully automated, real-time early fault detection and analysis system for improving semiconductor equipment and process productivity and various INFICON *in situ* diagnostic sensors. The powerful analysis techniques of FabGuard are capable of "smart diagnostics" by combining sensor and tool data for fault detection and classification. FabGuard puts *in situ* sensors to work to:

- Baseline normal process and tool behavior
- Analyze process data in real-time to detect problems and pinpoint problem sources
- Issue warnings and alarms

One of the benefits of FabGuard is the application of Statistical Process Control (SPC) to tool data for a PVD process. The FabGuard database is also mentioned, because the database is used to select which data is used for SPC.

Figure 1 shows raw tool data from one of the wafers used to create the SPC control charts shown later in this example. The lower plot shows the time series data for 3 variables: DC Power (red), Pressure Manometer (green), and Wafer Temperature (blue).

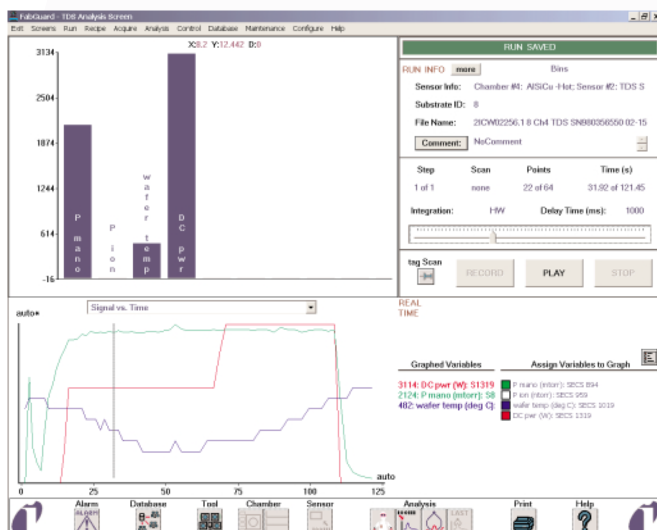

Figure 1. Raw tool data from one of the wafers used to create SPC control charts.

Figure 2 shows the FabGuard database query filters used to create an SPC control rule. The control variable is Wafer Temperature. The data used to create the control limits is from one chamber on one tool, for one recipe, for one day.

Figure 2. FabGuard database query used to create an SPC rule for Wafer Temperature.

Figure 3 shows the X-bar S control chart created from the database query of Figure2. In an X-bar S control chart, “X-bar” means that the controlled quantity is the average value of the control variable and “S” means that the control limits are calculated from the standard deviation of the control variable. In this case, the control variable is Wafer Temperature and the average and standard deviation are calculated in the time interval of 30 to 90 seconds after the start of each wafer. In the plot, X-bar for each wafer is plotted as a solid circle and the upper and lower control limits (UCL and LCL) are plotted as horizontal lines. The numerical values of UCL and LCL are estimates of ±3 sigma from the average. UCL and LCL vary for each wafer, because a slightly different number of samples was used for each wafer. The color of the symbols changes every time a new lot starts.

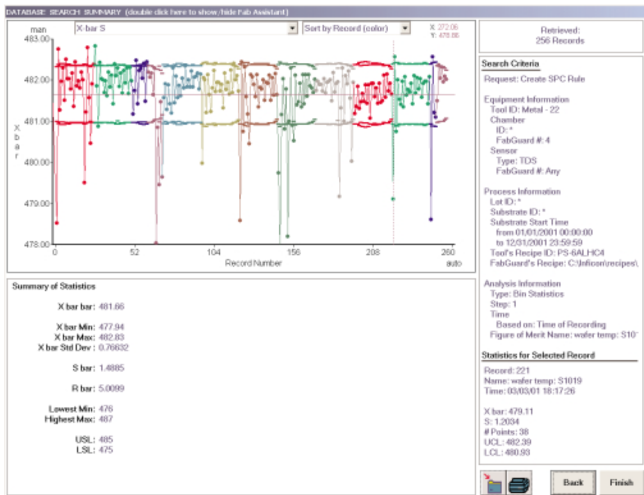

Figure 3. X-bar S control chart for Wafer Temperature.

A summary of the SPC statistics is given below the plot. X-bar-bar is the average of the X-bar values for each wafer. In the plot, X-bar-bar is the narrow horizontal line at the midpoint of the data. S-bar is the average standard deviation within each wafer. For Wafer Temperature, X-bar-bar is 481.66 degrees C and S-bar is 1.49. The ratio of S-bar to X-bar-bar is only 0.3%, which means that the Wafer Temperature varied by an extremely small relative amount.

Several wafers are outside of the SPC control chart limits, UCL and LCL. This implies that the process is out of control, in an SPC sense. However, all of the wafers are inside the specification limits, USL and LSL, so the process is performing acceptably well with respect to Wafer Temperature.

The control chart for Pressure Manometer is similar to the one for Wafer Temperature, so it does not need to be discussed here. The control chart for DC Power, shown in Figure 4, is more interesting. All of the data is inside the SPC control chart limits. However, starting in the fifth lot (around wafer 100) there is a significant shift in the mean. The mean shift is large enough that all of the wafers in the next 6 lots are above the upper specification limit, so the process is performing quite poorly with respect to DC Power.

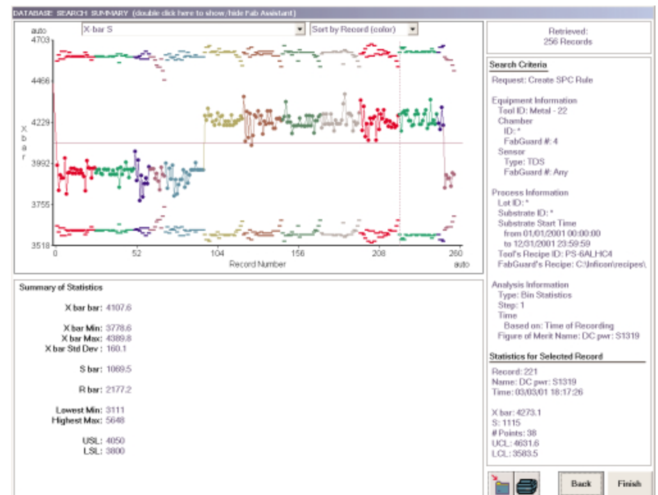

Figure 4. X-bar S control chart for DC Power.

Figures 3 and 4 were selected specifically to demonstrate that care must be taken when applying SPC. Although some of the data in Figure 3 is outside its SPC control chart limits, the process is still performing in spec. In contrast, although all of the data in Figure 4 is inside its SPC control chart limits, the process is performing out of spec.

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