INFICON

TECHNICAL NOTE

Principal Component Analysis for Fault Detection on Implanter with FabGuard®

FabGuard Sensor Integration 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 use of Principal Component Analysis (PCA) for fault detection using tool data. The process is ion implantation. PCA is a multivariate statistical technique that combines data from many variables based on each variable's variance and on the correlation between different variables. In this example, PCA is used to detect a fault rather than to detect endpoint.

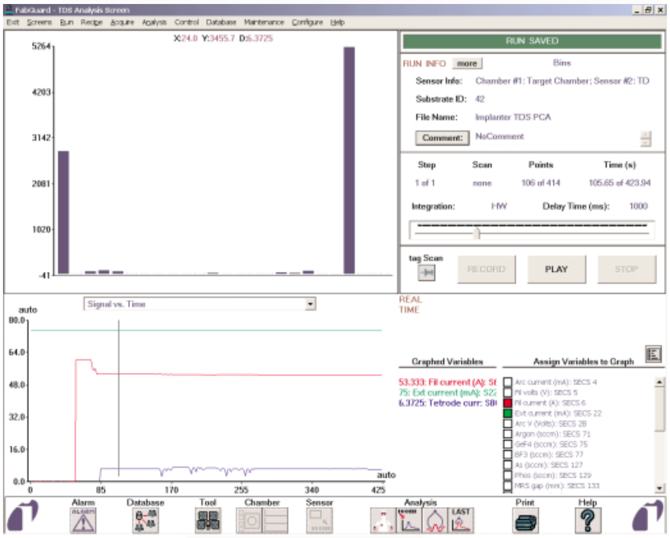

Figure 9. Typical implant tool data.

Figure 1 shows implant tool data. Data was collected for 24 different tool variables. The lower plot shows the time series data for 3 of these variables: Filament Current (red), Extraction Current (green), and Tetrode Current (blue). This data is from a typical implant run.

The goal of PCA fault analysis by FabGuard is to use typical data for training, to create a PCA model of the prototype process. Then the PCA model is applied to the data from every new run as the run proceeds. If a new run is substantially different from the prototype model, FabGuard will detect this difference and generate an alarm.

Figure 2 shows how PCA fault analysis is setup in FabGuard. In this example, the training method is T2. T2 provides a measure of how close the set of all 24 variables is to their normal values. No special knowledge of the meaning of each variable is needed. The PCA model was created from three implant runs that did not have any faults.

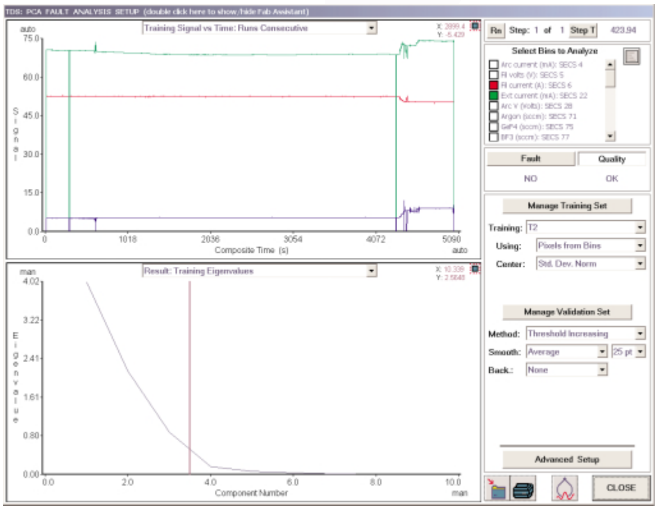

Figure 2. PCA training. T2 is used, keeping 3 principal components. The training set is based on three implants runs that did not have any faults.

Figure 3 shows how the PCA model is applied, which is referred to as validation. The validation set includes the three training runs plus a fourth run that exhibits a fault. The fault in the fourth run is clearly evident as the large peak just after 5000 seconds in the lower plot. Figure 4 is the same as Figure 3, except the vertical scale of the lower plot has been expanded by a factor of 100. For the fault-free training runs, the largest value of T2 is 20. For the fourth run, the largest value of T2 is more than 7000. This gives a signal to noise ratio of 350, which is sufficient for robust fault detection in this process.

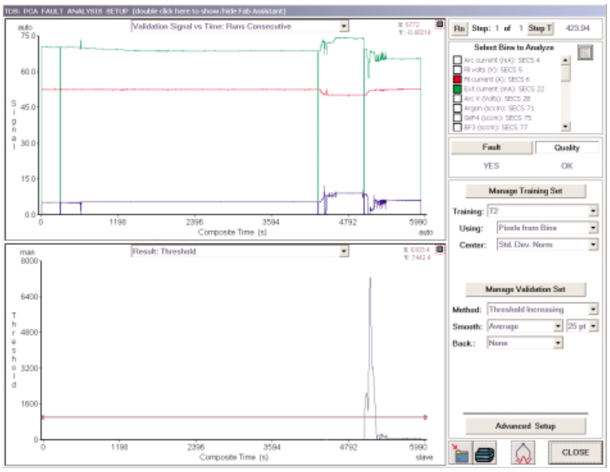

Figure 3. PCA validation and fault detection. The validation set includes the three training runs plus a fourth run that exhibits a fault. The fault in the fourth run is clearly evident as the large peak just after 5000 seconds

Figure 5 shows the raw data for all four runs from the validation set. Looking at the raw data for individual variables, it is not obvious that the fourth run, which starts just after 5000 seconds, contains a fault. Only 3 of the raw variables are plotted in Figure 5, but none of the other 24 variables are any more useful for predicting a fault. Only PCA, which includes correlation between all 24 variables, is able to unambiguously identify the fourth run as substantially different from the first three.

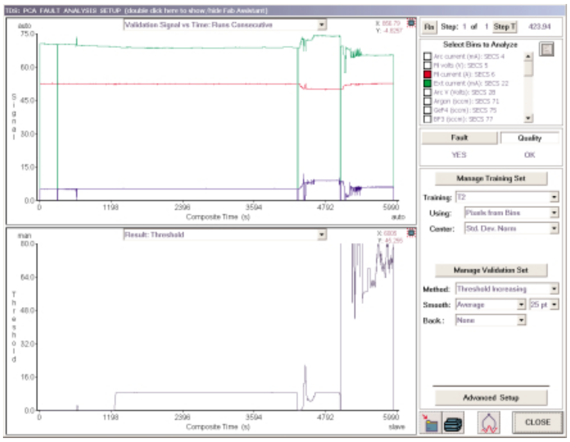

Figure 4. PCA validation and fault detection. This is the same as the previous figure, except the vertical scale of the lower plot has been expanded by a factor or 100.

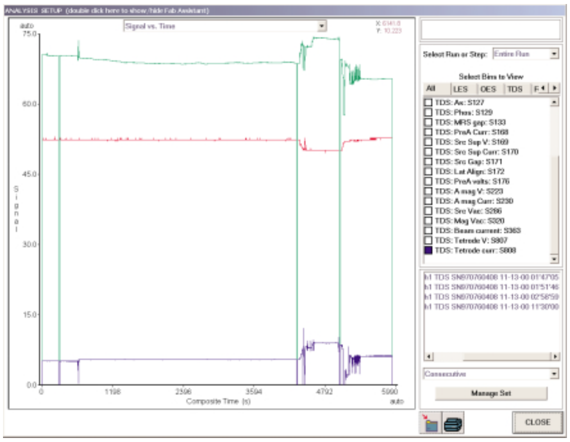

Figure 5. Raw tool data for all four runs in the validation set. The run with the fault starts just after 5000 seconds. The fault is not evident in the raw data.

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