SIMCA®

Application Note

Semiconductor Regression Example

10 June 2020

Virtual Metrology

Making a computer chip starts with the building of layers, both metal and insulator, onto a silicon wafer. Each wafer goes through hundreds of process steps before it can be sliced up into the computer chips that we use in our cell phones, laptops, and game consoles. To make sure that each piece of equipment is performing to specification, intermediate measurements are taken after every few steps. These measurements are done on metrology equipment and consist of properties like thickness, uniformity, and critical dimension. Metrology information is necessary for quality assurance purposes, but metrology equipment is costly and taking time to measure wafers decreases throughput. Virtual Metrology (VM) is a software system that uses available data to predict metrology measurement values for every wafer processed through a step based on correlations found in the process data. Time series process data is used to build a PLS model that can predict the metrology outcome immediately after processing is complete. Possible benefits of VM include: reduction in test wafer usage, reduction in cycle time, reduction in metrology capital cost, reduction in rework rate, reduction in mean time to detect a process shift and/or drift, improved yield, improved closed loop control systems, and improved dynamic sampling for metrology.

Semiconductor Example

In this example, data from an oxide CVD process and its corresponding thickness measurements was used to build a virtual metrology model. Although collecting data using a design of experiment is recommended, it is extremely expensive, so we decided to see if historical data could provide the variation required to build a good predictive model. First, three months of process and matching metrology data was collected randomly across similar process chambers. A PLS model using this data was built and validated. Figure 1 shows the observed value versus the predicted value from this model. You can see there are seven wafers that are unusually thick compared to the others. Since this group is under-represented, these wafers were excluded during the test.

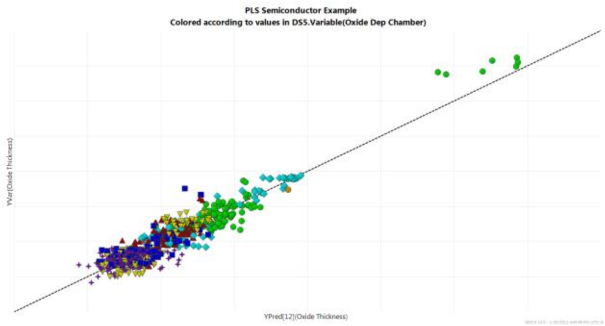

Figure 1: Data from several chambers is used to build a PLS model predicting oxide thickness. The plot is colored by the chamber that the wafers were processed on.

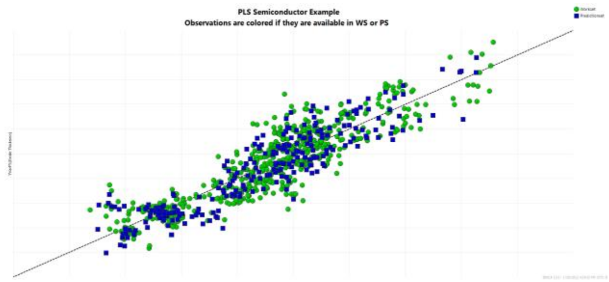

Figure 2: New data is collected and used to test and validate the model.

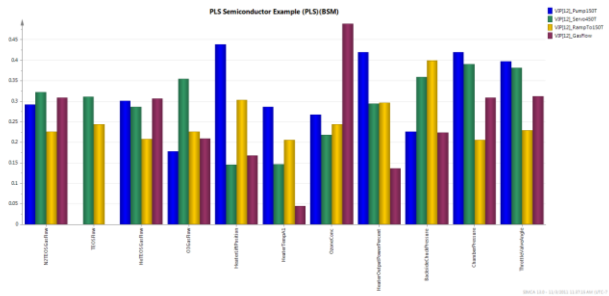

Figure 3: Variable importance plot for the validated PLS model.

The model was verified with new data collected over the following week. Figure 2 shows the observed value versus the predicted value of both the model and the test (prediction) set. The plot color indicates the group in which the wafer belongs. Now that the model has been validated, the variables that are strongly predictive of thickness become interesting information for the process engineer. Figure 3 shows the variable importance plot by process step.

This model was then used to predict metrology over the next 15 weeks, and the delta between the measured wafer values and the predicted values was used to calculate model performance (Figure 4). The maximum median delta value over the 15 weeks was 5 Angstroms. The control limit for this process was +/- 15 Angstroms, and the spec limit was +/- 25 Angstroms.

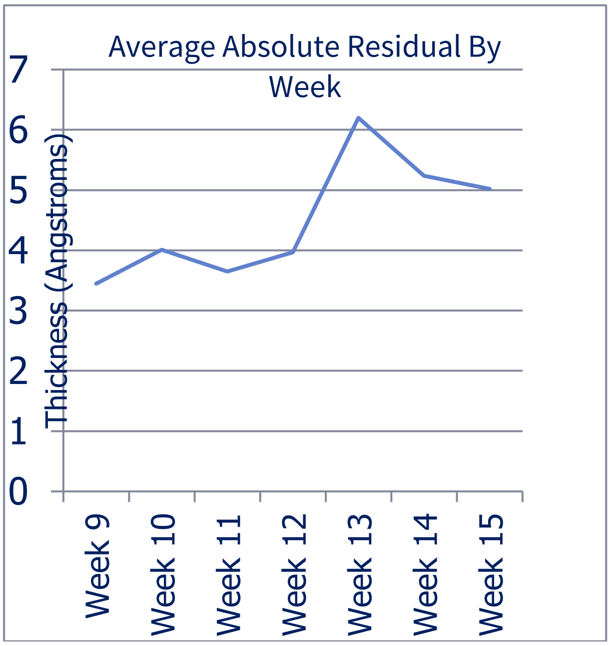

Figure 4: Average absolute residual by week.

Summary

We have seen the value of virtual metrology demonstrated across many different tool types. Applications in which it has been successfully implemented include reactive ion etch, physical vapor deposition, and chemical vapor deposition. Experience in applying virtual metrology has shown that the most efficient return on investment is achieved by the investigation of correlations between quality and process variables. It is important to remember that although a process may seem like it would support VM, thorough investigations of the correlations should be done in advance – and if possible, a design of experiment – before committing to delivery of useful online predictions.