Consolidation Method for SPC Data Review in a High Product Mix Semiconductor Fab

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Abstract

This paper presents a method for simplifying the sometimes difficult task of process control via SPC charting in a high mix semiconductor factory. We present a process for normalizing data allowing multiple data sets from a single process tool to be viewed on one chart.

INTRODUCTION

SPC charting is widely used in the semiconductor manufacturing business for process control. The benefits of making decisions based on SPC data have long been understood [1]. In a high volume manufacturing plant where product variation is minimal, a process engineer can more easily manage the number of chart reviews required to ensure their area of responsibility remains in control. In a high product mix factory, this task is multiplied by variation of processes and complicated by the sometimes long absences of certain production schedules. By normalizing multiple processes, each with unique targets, one can collapse the number of SPC charts needing review. Not only does the method described simplify the SPC review process, but improves the signal for low volume products.

This work utilized a commercially available production control software platform which include data collection operations and data charting interfaces. Our starting point for this work is data collection operations which reference absolute target values, upper and lower control limits, and upper and lower product specification limits. The data for each production lot was entered and compared to the defined limits. If the upper or lower control limit was violated, the process unit was taken offline. If the upper or lower product specification limit was violated, the production lot was put in a hold condition. In general, this is a simple and efficient system used by many semiconductor factories to maintain quality. In our factory, which processes hundreds of different products, each with unique process targets and limits, some which are processed regularly and others at irregular intervals, the full benefits of SPC are not realized [2]. Plotting data from all products on a single chart with fixed control limits is of no benefit if the production lots do not have the same target or limits. Plotting all data by product and process step maintains the SPC benefits only if the product is run regularly. Still, if many products are run regularly the number of charts requiring review becomes time consuming. Our solution to this problem is to normalize the data collection in a way that all data from a single processing unit can be meaningfully combined and plotted on a single chart, retaining the benefits of SPC while at the same time reducing the number of charts to a manageable level (Figure 1).

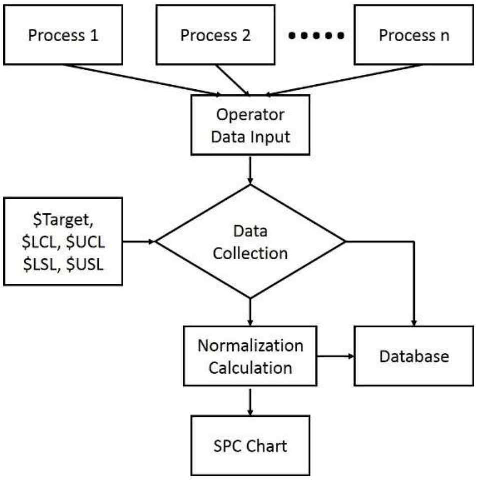

Figure 1. Data flow of multiple process steps from single entity feeding single SPC chart

PROCEDURE

The development and discussion of the procedures described in this work are based on the particular commercially available software platform used in our fab. In principal, this method applies to any SPC data logging method so the discussion will be kept general. The methods described are not inherent to our software, but are a function of how the monitoring system is set up. Our existing set up had data collection operations and SPC charts for each of the unique process recipes performed by a process unit, e.g. a low pressure chemical vapor deposition (LPCVD) tube. This process unit is responsible for depositing a multitude of layers of varying thicknesses or material properties. The individual data collection and SPC was a function of which recipe was being processed on the current lot. We include results in this work from an LPCVD system on production lots and a photoresist coat track on weekly SPC monitors.

As stated above, the data collection operation initially contained the upper and lower control and specification limits. The process result data was inputted, charted, and compared to the defined limits. A separate set up and chart was required for each of the process targets. The normalization process involves the addition of the target value as a variable, the definition of the control and spec limits as variables, and a normalization calculation. It is important that all the data (e.g. thickness and normalized thickness by process) are stored in the database and not just the normalized data without respect to process. The original data will be required to aid investigation whenever normalized SPC charts indicate a process violation, as described below. To facilitate multiple target values, our software allows the definition of variables by assigning "$" as the first character of a string to specify the variable name. This allows a single data collection setup for multiple processes with the value of the variables defined at the product or module level. In addition to the target value, the control and spec limits are also assigned to variables and set at a higher level. Setting the target and limits to variables is a key concept to using a single data collection setup for multiple process recipes.

For our example, only the calculated normalized data, %OnTarget, are sent to the SPC chart display while the raw input data, normalized data, current process step, and process entity are stored in the database. Our normalization calculation is defined as

$$\%OnTarget = 100 * \frac{(Actual - \$Target)}{\$Target}$$

RESULTS

The method was first applied to a stack of 4 LPCVD and Oxidation tubes. One process, LPCVD tube_1, required 14 separate SPC charts to monitor the process for thickness alone. See Figure 2, which maps the processes in LPCVD tube_1. Multiple data collects were defined, and multiple process targets were set up. Each line connecting the data collection operations and targets represents an SPC chart. Figure 3 represents a subset of 5 of the 14 charts. The 5 individual SPC charts are overlaid here on a single chart for convenience and control limits are left off for clarity. The 4 tubes in this stack required a total of 30 SPC charts. The process area had 2 other stacks of 4 tubes each as well as some additional processing equipment. The 3 stacks alone accounted for approximately 100 SPC charts. By the appropriate use of normalization, the method described collapses the number of charts from approximately 100 to 12 (1 per tube).

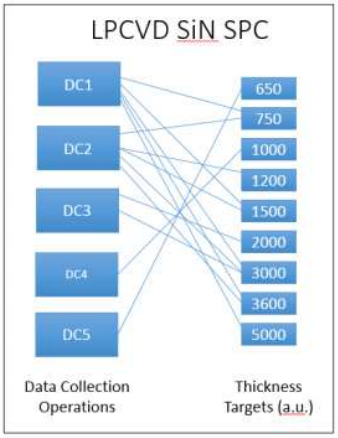

Figure 2: Initial state of LPCVD SiN SPC

Figure 4 shows the resulting single SPC chart representing the data from Figure 3 after the normalization calculation is applied. Note the information available from the final chart matches well the data from operation LP15K with a target of 1500A. The LP15K operation is run often and consistently. However, all 4 other processes represented in figure 5 have significant gaps or run at infrequent intervals. Without the normalization method, little information can be gathered from their individual charts.

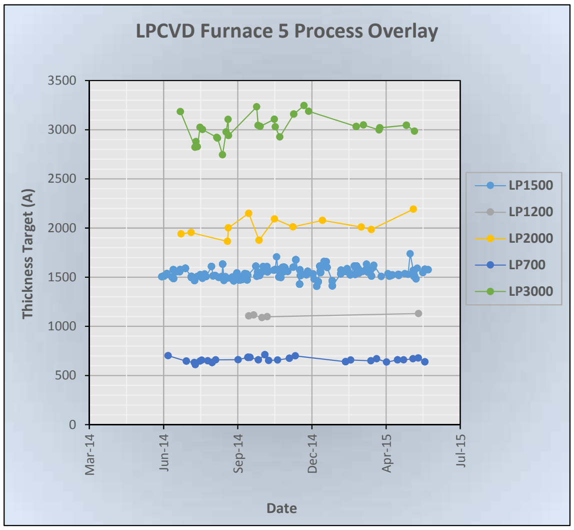

Figure 3: Overlay of 5 data collection sets from one LPCVD furnace. Without deviation method this required 5 separate SPC charts, some of which had long time spans between data entries.

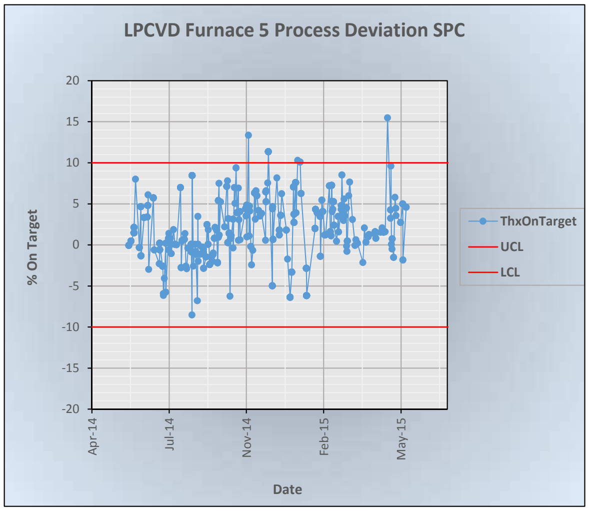

Figure 4: Data set from Figure 2 combined into a single SPC chart indicating the health of the process equipment.

The method was also applied to a photoresist coat track with different thickness coats and different viscosity resists. The track performs coats for low and high viscosity resists with thickness ranges from 2um to 8um requiring 9 thickness SPC charts per coat tool. The resist coat is checked weekly and used to monitor resist thickness and uniformity. Using the same procedure as used in the LPCVD SPC, our example shows how one resist, used for 5 coat thicknesses initially monitored with 5 SPC charts was reduced to a single chart. Figure 5 shows the individual charts, again plotted on a single chart for convenience. In this case, the deviation charts were confined to multiple thickness for a single viscosity. Each viscosity had a dedicated deviation chart. Figure 6 shows the resultant %OnTarget chart with the normalized data from Figure 5.

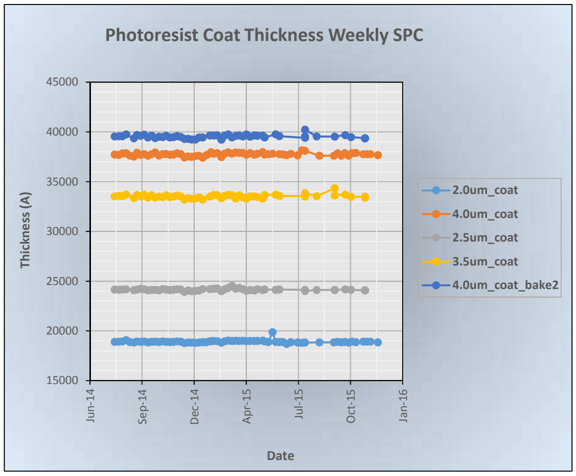

Figure 5: Resist coat track data representing 5 coat processes

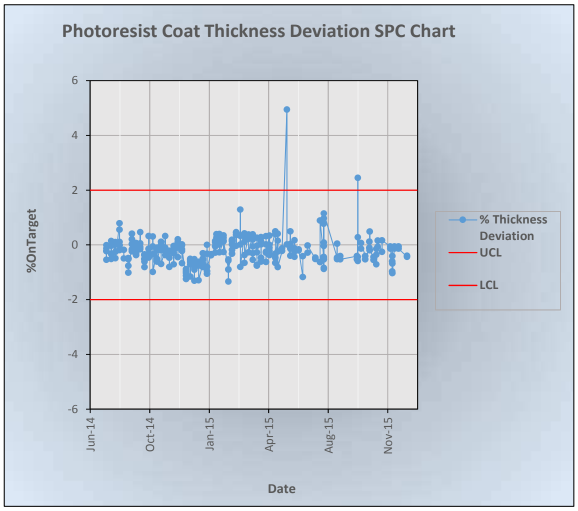

Figure 6: Coat track weekly thickness SPC %deviation chart

When signals appear in the normalized data it is desirable to maintain the ability to de-convolute the data in the event an investigation is necessary. Figure 7 illustrates the ability to separate the data from figure 4 using a probability plot [3] for post processing if necessary. Any standard statistical analysis tool can be used to separate the data as long as the data collection included the raw data in the initial setup.

A final consideration is mentioned here when deciding which data sets to combine on a single chart. For the LPCVD example above, all processes combined from figure 3 to figure 4 use similar chemistry and temperatures. Variables which influence one process are expected to influence all processes in a similar manner. When considering processes from another CVD tube which deposits both amorphous and polycrystalline films, it makes more sense to separate the processes into separate deviation charts. The amorphous film properties are a strong function of gas flows while polycrystalline properties are a stronger function of furnace temperature. Applying a normalization calculation to both processes together might yield misleading results. For the photoresist coat process, this same consideration led us to use viscosity consistent deviation charts.

CONCLUSIONS

SPC normalization method can be used to improve the efficiency of the analysis of multiple processes, especially processes from high mix semiconductor factories. The methods described were used across process technologies and are general enough to apply wherever SPC data is collected. If the data set retains the raw information as well as the normalized values, investigations can be carried out when signals appear.

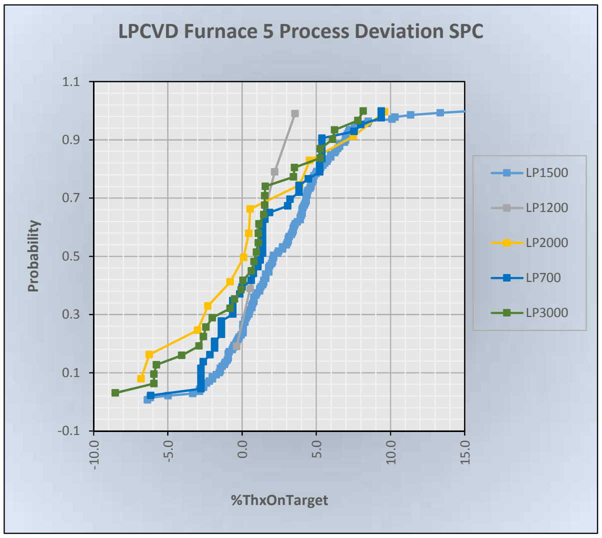

Figure 7: Probability chart by process step of deviation data demonstrating the ability to perform statistical analysis on the normalized data

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ACRONYMS

SPC: Statistical Process Control
LPCVD: Low Pressure Chemical Vapor Deposition