Accurate Statistical Process Control using an innovative approach based on Spatial Metrology information

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ABSTRACT

Motivation

As the complexity of fabrication processes increases and the wafer size grows, standard SPC indicators (like mean standard deviation and range) are too basic and no longer enough to achieve an accurate control over the whole wafer surface especially for complex shape of surface like CVD, CMP,…. On the other side, the information provided by Metrology tools is not being exploited in its full potential. Moreover, the spatial information carried by the coordinates of the measurement sites is not exploited at all. In a previous work (see citation below), we proposed a robust and reliable surface rebuilding algorithm (WaferFit) allowing us to compute a continuous representation of the wafer surface starting from standard Metrology output.

In this paper, we introduce a novel SPC approach that uses the representation of the whole wafer surface to compute a set of coordinate-dependent control limits. Hence, new control alerts are referred to specific regions on the wafer surface (in standard SPC they are referred to a single quantity, like the average, representing the whole wafer metrology).

Description of the approach

According to the traditional practice, the metrology of a set of wafers – or reference population -- is used to compute the upper and lower control limits. In our approach, we use the same reference population in the following way:

1. For each wafer, the continuous surface model is computed and projected over a “control mapping”. The control mapping is a dense set of sites providing a good sampling of the whole surface. The aggregation of these projections over the reference population forms a dense (interpolated) metrology reference set.
2. Each site of the control mapping, with coordinates (x,y), generates an individual control chart. In this way, for each coordinates (x,y), upper and lower control limits are computed.

The model described above is used as follows. Consider a test wafer:

1. Using WaferFit, the continuous model of the surface is built and its projection over the control mapping is computed.
2. For each site of the control mapping, the projected metrology is compared to upper and lower limits. If it is out-of-control, a control alert, *associated to specific coordinates (x,y)*, is raised. The final output is a map (the control mapping) of the wafer surface showing the out-of-control (upper and lower) site by site.

Results

The coordinate-dependent control alerts, described above, can be used:

- For standard control and run-2-run pre-treatment;
- For visualization purposes. Coordinate-dependent alerts can be displayed as if they were wafer surfaces;
- For classification purposes. The control map can feed an alert signature data base where the spatial signatures are control maps themselves.

We have tested this approach over complex surfaces using a 17-site metrology mapping and a 200-site control mapping. The first results show that the advanced SPC is more sensitive and accurate than standard SPC (see figures 1 and 2).

KEY WORDS: SPC, Metrology measurements, surface rebuilding, Machine Learning

CITATION: Alegret, Fernandez, Pasqualini; *Machine Learning for Metrology Applications in front-end Manufacturing: Adaptive Surface Reconstruction and Abnormal Profile Detection*. ISMI 2005, Austin Texas, USA.

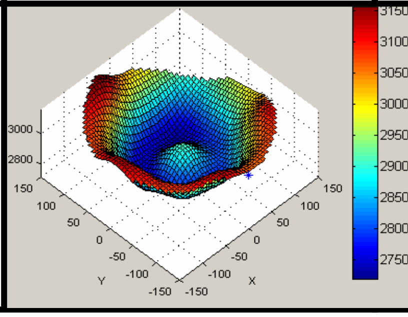
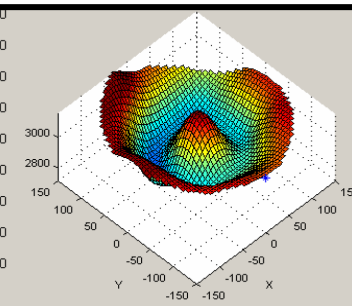
	Typical CMP profile	Abnormal CMP profile	
SPC Limits: **2950Å < Mean < 3450Å** **0 < Range < 200Å** **20 < Stdev < 270Å**			**Mean = 2980Å** **Range = 60 Å** **Stdev = 155Å**

Figure 1: For two months of CMP production, 21 abnormal wafers (as drawn) were **detected by the advanced SPC only** (not detected by standard SPC):

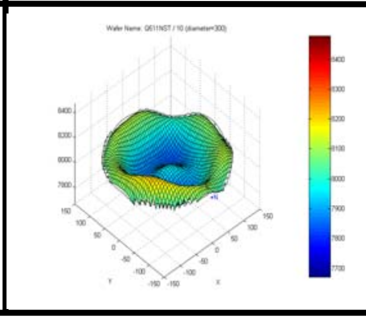
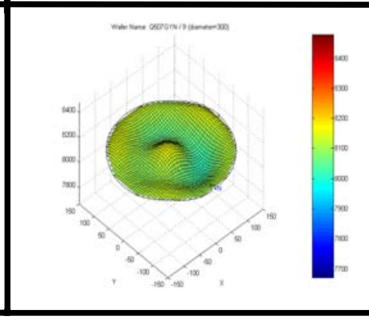
	Typical CVD profile	Abnormal CVD profile	
SPC Limits: **8050Å < Mean < 8350Å** **0 < Range < 50Å** **0 < Stdev < 140Å**			**Mean = 8100Å** **Range = 35 Å** **Stdev = 9.7Å**

Figure 2: For two months of CVD production, 10 abnormal wafers (as drawn) were **detected by the advanced SPC only** (not detected by standard SPC):