A solution for exposure tool optimization at the 65-nm node and beyond

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A solution for exposure tool optimization at the 65nm node and beyond

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ABSTRACT

As device geometries shrink, tolerances for critical dimension, focus, and overlay control decrease. For the stable manufacture of semiconductor devices at (and beyond) the 65nm node, both performance variability and drift in exposure tools are no longer negligible factors.

With EES (Equipment Engineering System) as a guidepost, hopes of improving productivity of semiconductor manufacturing are growing.

We are developing a system, EESP (Equipment Engineering Support Program), based on the concept of EES. The EESP system collects and stores large volumes of detailed data generated from Canon lithographic equipment while product is being manufactured. It uses that data to monitor both equipment characteristics and process characteristics, which cannot be examined without this system.

The goal of EESP is to maximize equipment capabilities, by feeding the result back to APC/FDC and the equipment maintenance list.

This was a collaborative study of the system's effectiveness at the device maker's factories. We analyzed the performance variability of exposure tools by using focus residual data. We also attempted to optimize tool performance using the analyzed results.

The EESP system can make the optimum performance of exposure tools available to the device maker.

Keywords: EES, EESP, Data analysis, APC, FDC

1. INTRODUCTIONS and MOTIVATION

As the critical dimension tolerances decrease, process controls are shifting from the lot level to the wafer level. Sometimes, control on the shot level is desired. At various times in the past, shot level information has been used, on a temporary basis, to evaluate product and equipment precision. However, there are many implementation issues associated with shot level information that is acquired during device processing. Due to the volume of the data, it is difficult to evaluate immediately and to store over an extended period of time.

The EESP system was developed to overcome these hurdles in order to improve the production efficiency of semiconductor manufacturing systems. Large amounts of data must be cooperatively with device manufacturing

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engineers and the equipment suppliers.

We assumed that we could see each tool's condition and their product's condition from our analysis of them. After the characteristics were realized, it could lead to new compensation or operation methods for tools and production control to improve manufacturing.

In this paper, we show a new method to characterize tools using shot level data. We have confirmed the effectiveness of the new method by simulating the shot compensation.

2. EXPERIMENTS and RESULT

2.1 Status Identification from tool running data

This was an attempt to identify equipment and process status from stored data. We targeted the Canon 6000-series tools. The data was collected over a period of six months from a device maker's manufacturing factories. We collected shot level equipment data, then used the focus residual average from a shot, since it affects line-width accuracy. For the purposes of this test, shots were restricted to an area within a 130 mm radius from the wafer center. The reason was that shots on the edge of the wafer are often only partially whole. For these shots, focus is determined across the portion of the shot which is on the wafer. Additionally, the device makers may choose to drop shots at the edge of a wafer.

To identify equipment and process status, we plot the focus control results from 30,000 shots. Fig.2.1.1 shows that the distribution profiles were different for each exposure tool.

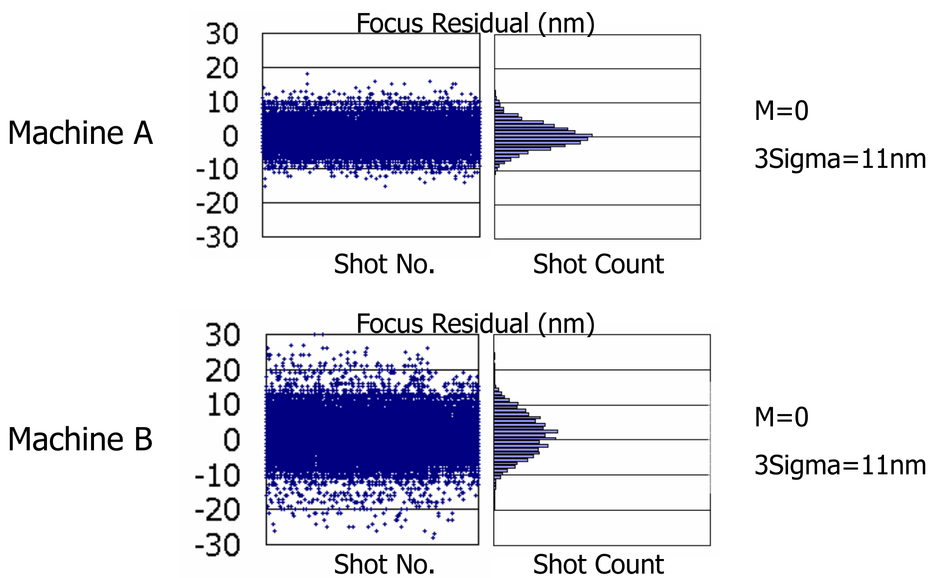

Fig.2.1 Focus residual result at each shot

Fig.2.1.2 shows the focus residual result distribution by "shot layout map". A shot layout map shows shot position on a wafer with the measurement result for each shot. The shot layout is different for each process. We chose to compare a number of different processes from one tool. As a result, the distribution was different between those processes. Also, there were differences between adjacent shots. This correlates with scan direction (up/down).

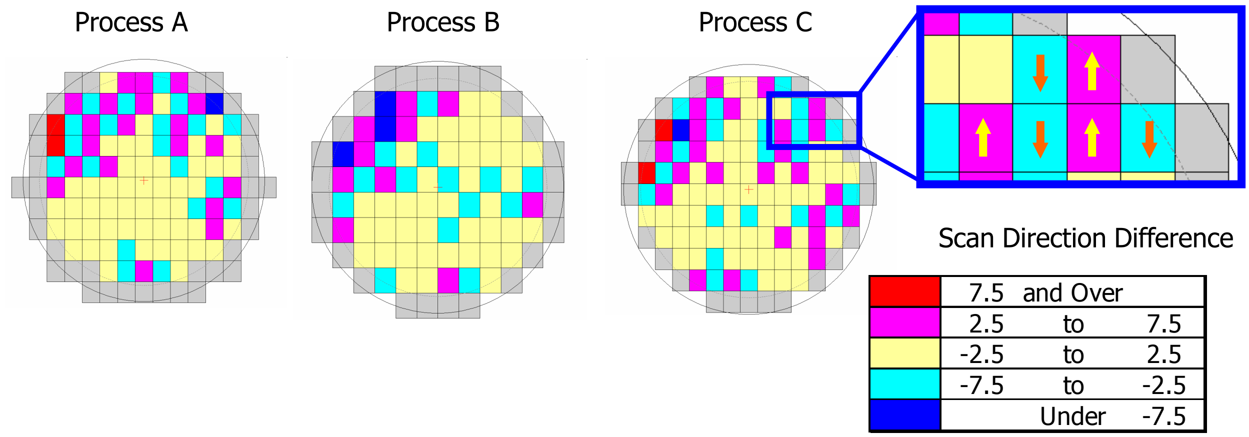

Fig.2.1.2 Focus residual result distribution on a shot layout Map

From these shot layout results, one could not distinguish whether the cause of this phenomenon was due to equipment characteristics or process characteristics.

2.2 Tool characteristic extraction by Grid Map Method

To separate these two types of characteristics, we attempted to extract the tool characteristics. We assumed that process characteristics are inconspicuous in the average of mass data from many processes.

To average the data at each shot position, shot layout differences among the processes made it difficult to uniform the data.

As Fig.2.2.1 shows, to eliminate the shot layout differences, we converted each shot layout into a common layout. This common layout is hereinafter called a “Grid Map”.

With the Grid Map, we can calculate the average at each grid position from various process data. Fig.2.2.2 shows the results of the Grid Map from the focus residual data. Data was taken from 30,000 shots. We checked two tools for each scanning direction. From the results, we realized that the focus residual volume was large at some specific areas. The location of these areas was different between tools. We also found that the values had opposite signs, depending upon the scanning direction. This phenomenon was shown at both tools. We considered it to be a tool error, in the category of a real time control error.

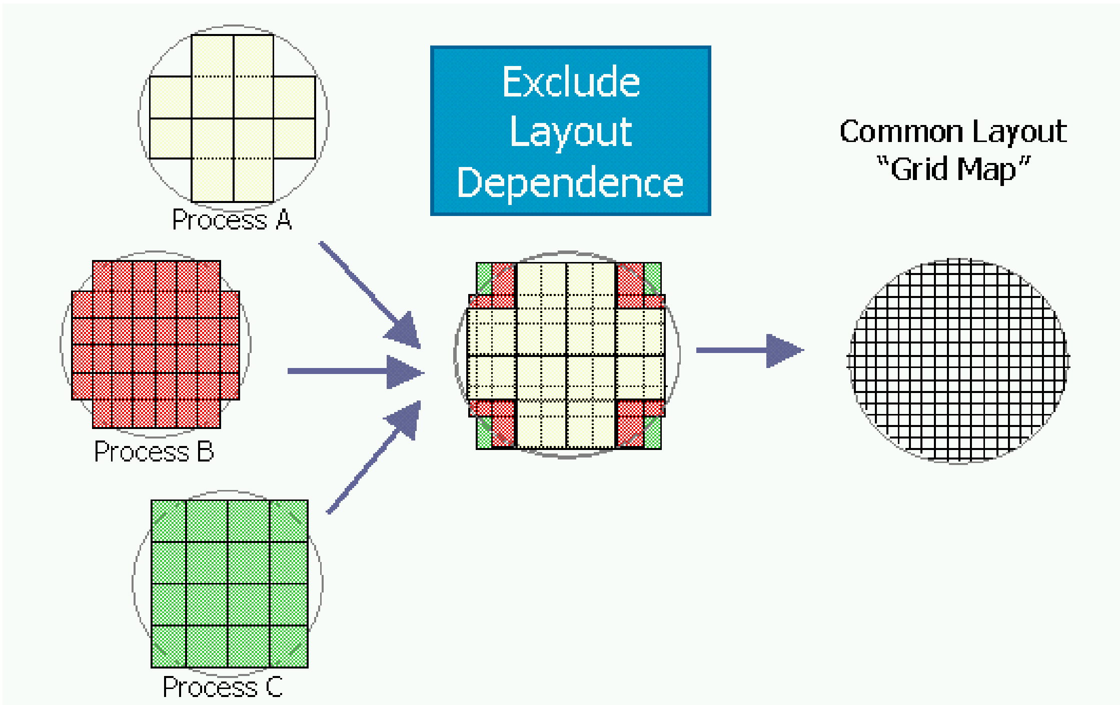

Fig. 2.2.1 Grid Map converting method

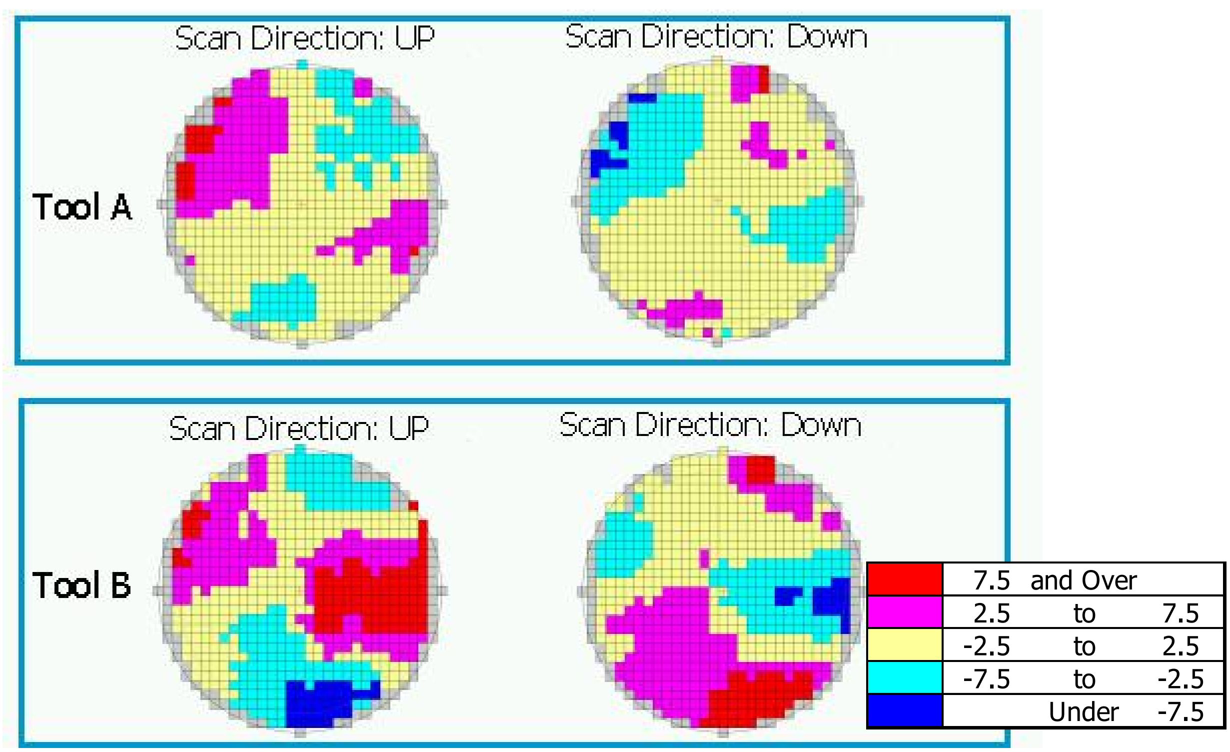

Fig. 2.2.2 Averaging Result by Grid Map

2.3 Shot compensation

As a result of the extraction of a tool's characteristics, we found position dependency and scanning direction dependency. Using this result, we compensated the tool to verify that those dependencies were tool characteristics. As Fig. 2.3.1 shows, we calculated the compensation value for each shot for each process from the results of the Grid Map.

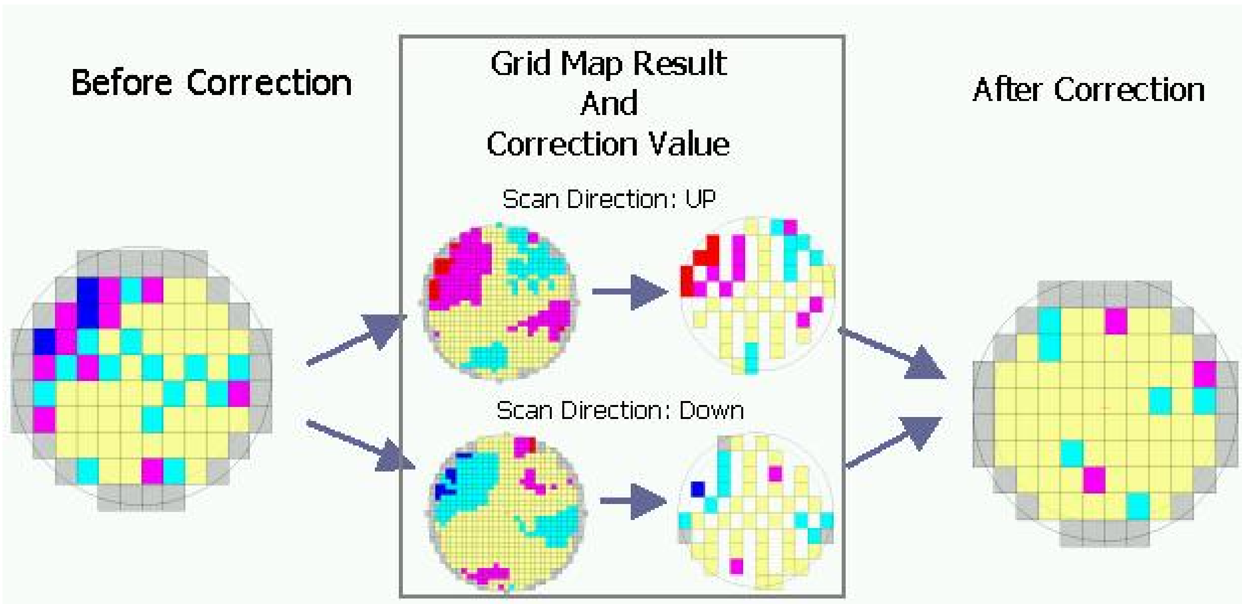

Fig. 2.3.1 Simulation method for shots compensation

We simulated the compensation by subtracting the compensated value from the shot acquisition data. Fig.2.3.2 shows the results of compensation for three processes. From the shot layout maps, one can see that shots were compensated across the wafer. From the graphs, the distributions were reduced from 3sigma = 11nm down to 3sigma = ~5nm.

Also, we tested compensation of all processes over a period of three days. Fig. 2.3.3 shows the results of compensation for two tools. The 3sigma of the distributions was reduced from 11nm down to 6nm in one tool, and from 19nm down to 8nm in another tool.

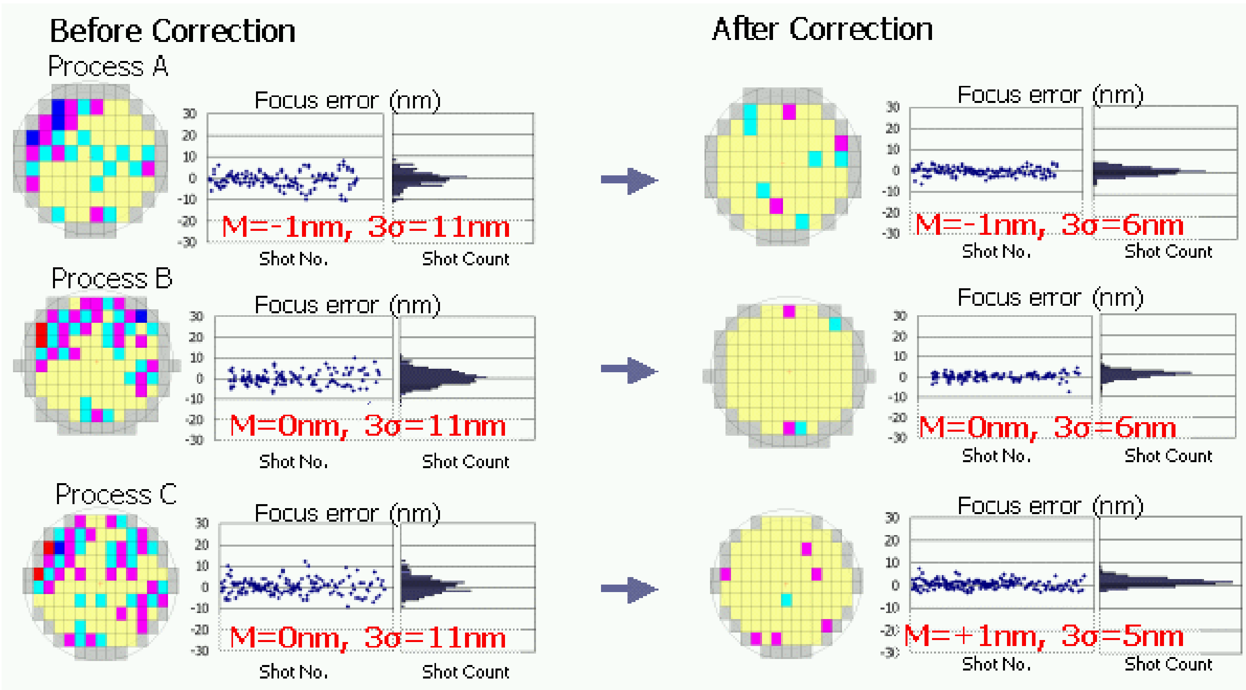

Fig. 2.3.2 Correction result for three processes

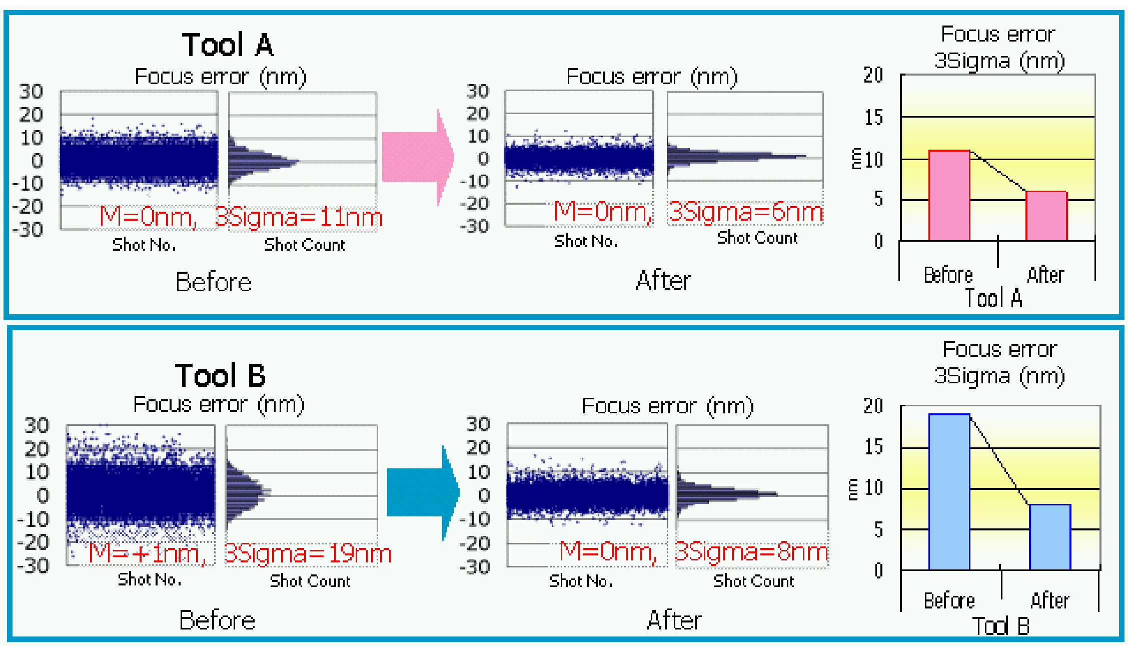

Fig. 2.3.3 Correction result for all processes

2.4 Drift monitoring and compensation

Fig.2.4.1 shows how the focus error changes in time. An "area map" is used to examine a change which is a function of time. The map divides the wafer into a number of areas. This map integrates the several hundreds cells of grid map into several tens of area. It simplifies distribution on wafer to monitor the distribution change in graph.

Each area shows a change as a function of time. In each area, we looked at the amount of change for the offset value. From the graph; all the data was normalized to the first point, we can understand when the correction value should be changed.

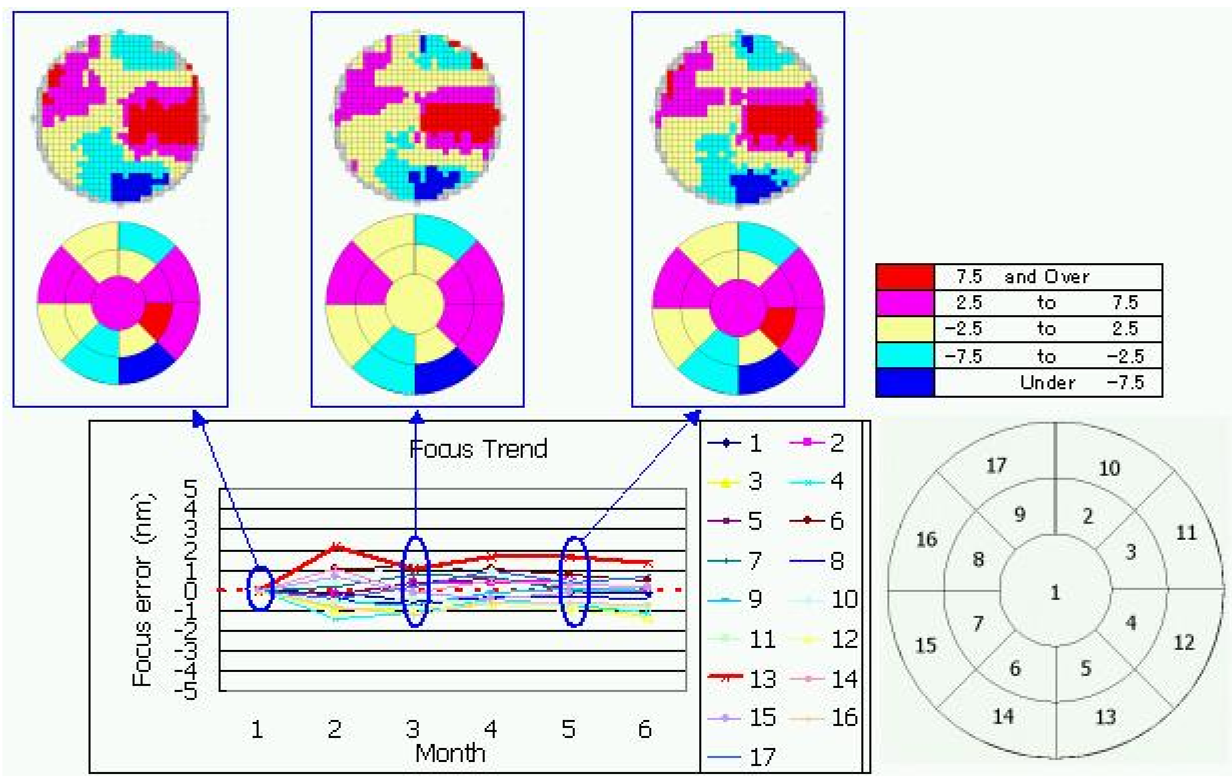

Fig. 2.4.1 Focus error drift monitor by Area Map

3. CONCLUSION

We developed the EESP to acquire equipment data from running lithographic systems over an extended period of time. The system can be used to search for ways to improve product accuracy by identifying equipment and process status.

For a characterization of the lithographic equipment, the initial step took shot-level data from equipment operation results. We visualized equipment status on the shot level as a distribution on the wafer by the Grid Map. We confirmed ship position dependent error and scanning direction dependent error from the Grid Map. Correction simulations was done to every shot based on this identified equipment status. The 3 sigma distribution of focus error average in shot was reduced to one digit. This compensation will be effective at device products of 65nm node and beyond. Also, monitoring change of distribution on wafer was seen over an extended period of time. We confirmed that EESP could do characterization and monitoring by statistically process a large volume of shot-level data and summarize without pausing production.

Product accuracy heavily depends on the semiconductor manufacturing system, and it is important to operate the system efficiently. In the future, equipment optimization from massive data analysis though EESP will be an indispensable item.

4. ACKNOWLEDGEMENT

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