Tighter Process Control of Poly and Active to Contact Overlay Registration via Multi-layer Analysis

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ABSTRACT

As process technology in high volume production fabs hits the 180nm window, overlay metrology of the most critical layers needs to be managed very carefully. As feature sizes and other device characteristics shrink, the overlay requirement becomes a larger component of the overall process specification.

It is no longer sufficient to measure overlay for only two layers at a time. In no other part of the process is this more critical than the poly and active layer to first contact. The contact layer needs to be aligned to both active and poly within tight tolerances. Since adjustments to overlay for these levels are not independent, it is essential to understand the relationship between all three layers. TSMC in particular, because it is a foundry, is not able to optimize customer circuit design that would allow two-layer registration to be sufficient. Previously, the only method to accomplish this has been to make two sets of overlay measurements and having an engineer analyze the relative overlay between the three layers.

The proposed solution to solve this problem is a multi-layer overlay measurement algorithm and measurement target. This paper will report on the analysis of the process improvements that have and can be achieved using this unique measurement capability.

1. INTRODUCTION

The process technology node for this work is 180-nanometer half pitch. The resultant overlay specification is 60 nanometers. This specification is aggressive for the scanners for standard two-layer overlay. The process is most critical at first contact and has a direct impact on yield. Not only is this the primary contact to poly, it must also align to active nitride. Diagram 1 shows a typical process gate structure with alignment to the two substrate layers. We will call this multi-layer metrology. The same specifications that are put on all critical two-layer overlay must also hold for this three-layer overlay requirement.

In this paper, we will first demonstrate the need for multi-layer metrology. This will be done using production data from TSMC Fab 6. In this first section, we will also discuss the benefits of multi-layer Monolith analysis of the data. We will then propose a new target design and algorithm that will allow for the automated measurement and analysis of the multi-layer process.

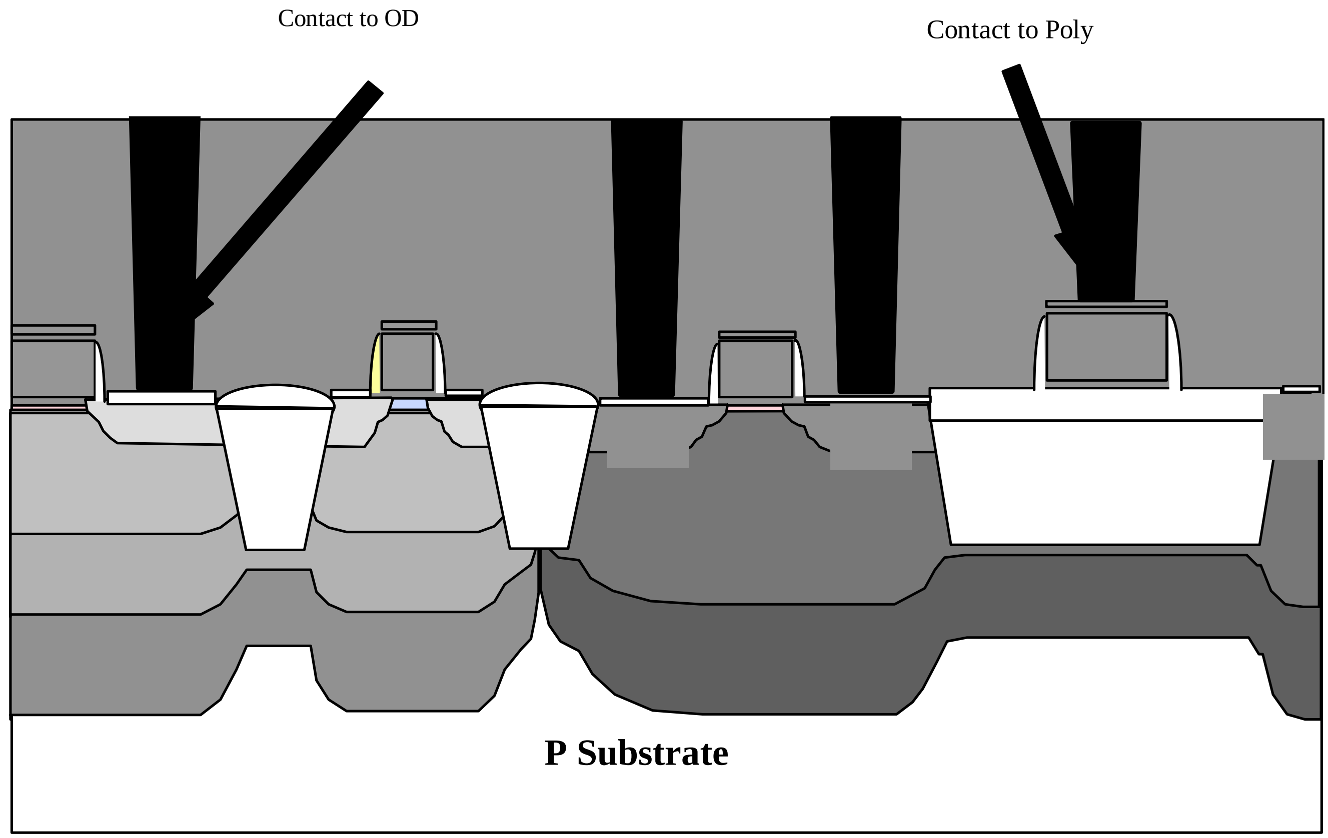


Diagram 1 - Process stack showing contact 1 to active nitride and poly-silicon

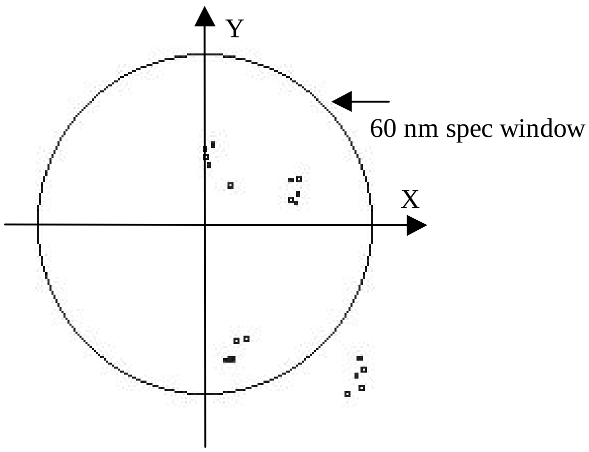
2. MULTI-LAYER REQUIREMENT

The purpose of the following experiment was to show that using the data from a combined multi-layer measurement of the poly-silicon to first contact and active to first contact overlay will better control the 0.18-micron process at TSMC. The data was taken from 63 random production lots at TSMC's Fab 6 in Tainan Taiwan. The measurements were made on a Schlumberger IVS 130 metrology system. Data was analyzed using Monolith overlay analysis software from NVS.

The statistical and modeled monolith data from 63 production lots were then placed in a spreadsheet and the combined values were then calculated by averaging the two data sets. A straight average was calculated for each data pair of active and poly. The data was taken from the same wafers at the same locations. This gave us a true multi-layer data set. From that data set a series of simulations was executed in Monolith to show the effects of different corrections on the data. A sample lot was then analyzed and shown below.

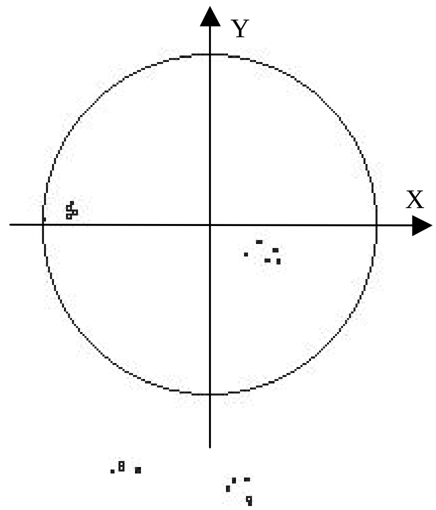
Two types of plots are used to display the data. The first is the bulls-eye plot. This plot will show the data relative to the specification in a bulls-eye configuration. The center of the bulls eye represents the target value, 0 nm overlay displacement in this case. These plots show clearly the data that is within specification and the data that is outside of the specification window. The second plot is the yield map. This is a simulation that shows when percentage of the wafer will yield based on overlay data available. The yield is determined by extrapolating the overlay data from the test fields and calculating what fields would be in and out of specification. This is a quick way to see the effects of the scanner corrections applied.

Diagram 2 and 3 show a sample lot where the data for both the poly-silicon to contact and the active to contact has some out of spec data.



Active to Contact – Raw Data
Within Specification 15
Outside Specification 5

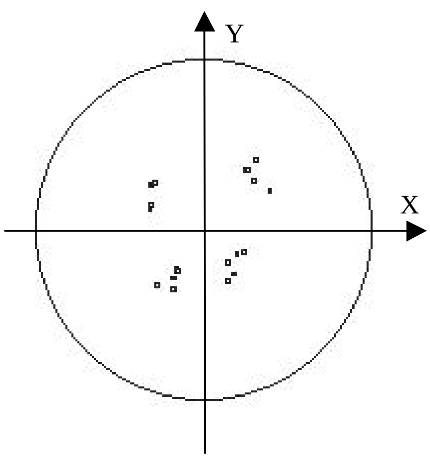
Diagram 2



Poly-silicon to First Contact – Raw Data
Within Specification 10
Outside Specification 10

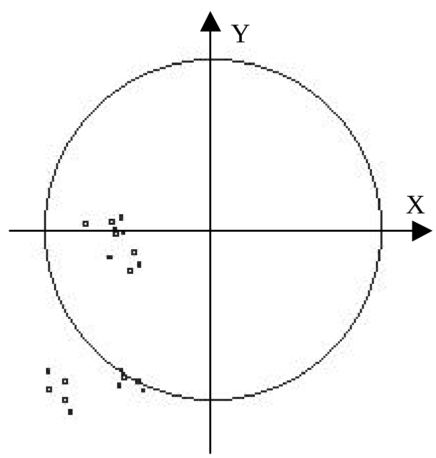
Diagram 3

The correction coefficients from the active to first contact are then applied and the results are shown below.



Active to Contact – Active Correction
Within Specification 20
Outside Specification 0

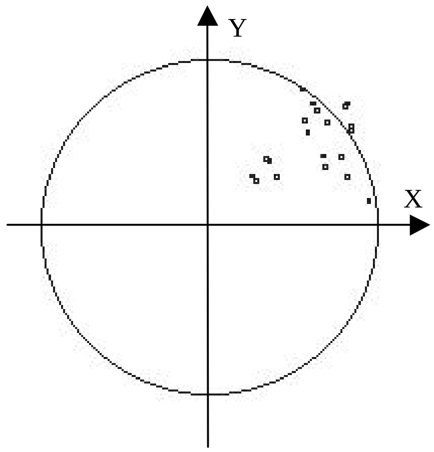
Diagram 4

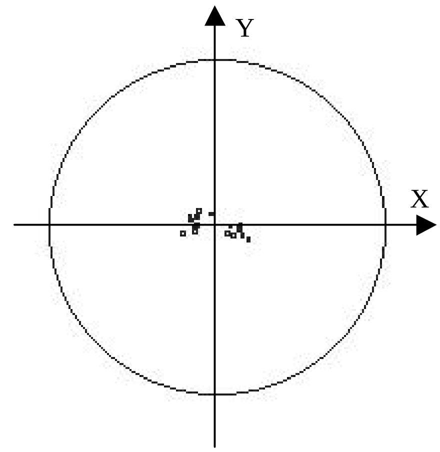


Poly to First Contact – Active Correction
Within Specification 12
Outside Specification 8

Diagram 5

With the correction applied for it, the active layer data is within specification. The poly-silicon layer, however, still has eight data points out of specification. This is because the registration offset between the active and poly-silicon layers has not been taken into account. The next plots show the effect of using the poly-silicon correction coefficients for both layers. As expected, the poly-silicon layer is now within specification and the active layer is not.





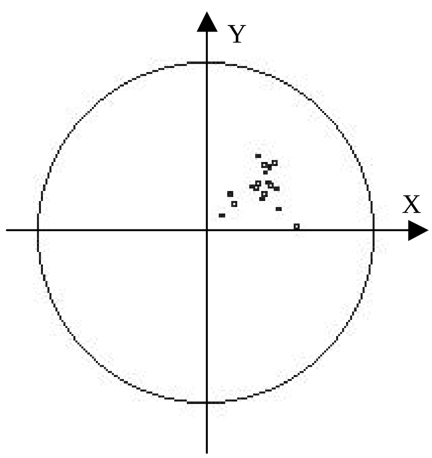
Active to Contact – Poly Correction
Within Specification 16
Outside Specification 4

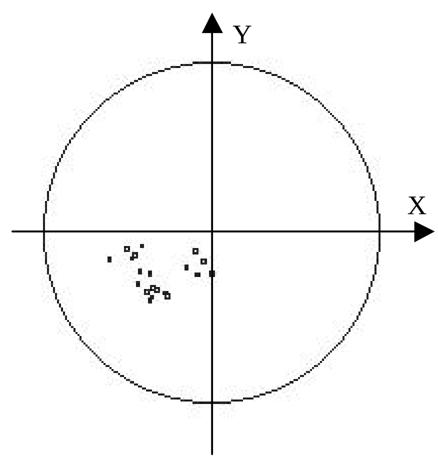
Diagram 6

Poly to First Contact – Poly Correction
Within Specification 20
Outside Specification 0

Diagram 7

Taking the combined multi-layer coefficients for the active and poly-silicon to first contact results in the following plots.





Active to Contact – Multi-layer Correction

Within Specification 16
Outside Specification 4

Diagram 8

Poly-silicon to First Contact – Multi-layer Correction
Within Specification 20
Outside Specification 0

Diagram 9

The above data clearly shows that when the multi-layer coefficients are applied, both the active to first contact and the poly-silicon to first contact overlay data is within specification.

The data is also backed up by the following yield analysis simulation, which shows how the fields that would be effected by the overlay errors displayed above. The simulation yield maps show bad die in dark gray, questionable die in medium gray and good die in light gray.

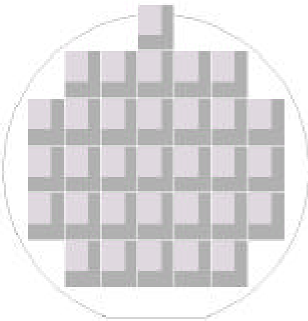


Diagram 10

Yield Map
Active – raw data
Good Die 128
Bad Die 0
Questionable 160

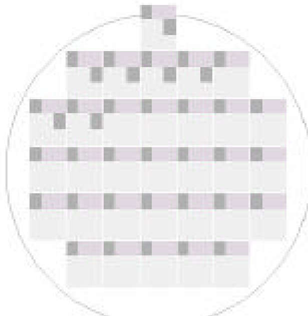


Diagram 11

Yield Map
Poly – raw data
Good Die 64
Bad Die 185
Questionable 39

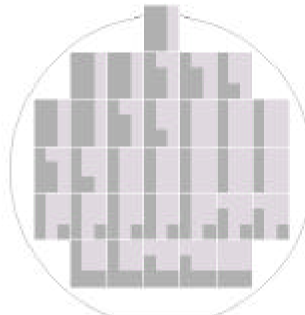


Diagram 12

Yield Map
Active – Poly Corrections
Good Die 155
Bad Die 0
Questionable 133

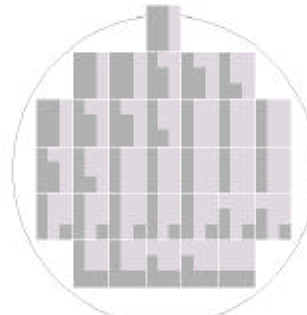


Diagram 13

Yield Map
Poly – Active Corrections
Good Die 156
Bad Die
Questionable 132

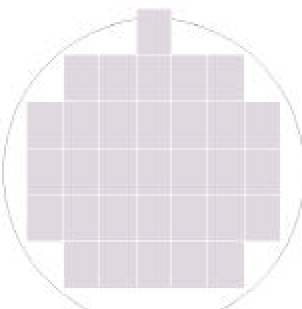


Diagram 14

Yield Map
Active – multi-layer correction
Good Die 288
Bad Die 0
Questionable 0

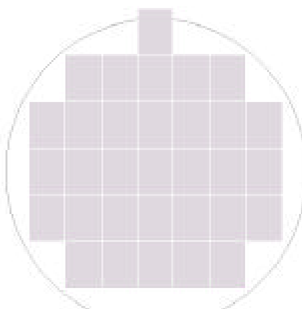


Diagram 15

Yield Map
Poly – multi-layer correction
Good Die 288
Bad Die 0
Questionable 0

The above simulations show that not until the multi-layer coefficients are used to correct the scanner's errors does all of the data come into specification and all of the die will yield.

3. MULTI-LAYER FEATURE AND ALGORITHM

The data analysis above shows the need for multi-layer measurements. The current methodology employed at TSMC and other leading edge fabs throughout the world is to measure the active to first contact and poly-silicon to first contact separately and then average the data off line. This is done to give pass-fail criteria for the lot. The monolith data can not be calculated easily to determine the average adjustment that is required for the scanner. Since this generally requires engineering or operator intervention, it is not a process that is very production friendly. It also requires two complete sets of measurements on the metrology tool.

The need arose for a multi-layer measurement where the registration between all three layers was measured at once. A new measurement feature would be required to show the overlay of all three layers at the same time as well as a new algorithm to make the measurement all at once. This would allow for in line analysis of the combined multi-layer data as shown in the data analysis above via Monolith and feedback to the scanner if necessary.

It also allows for a significant throughput improvement. The measurement of a multi-layer feature would take a matter of a few milliseconds more per site than the standard measurement algorithm versus twice as long measuring both layers separately. This would increase the productivity of the overlay metrology tool by five to ten percent depending on the number of total layers measured for overlay. The improvement would not just be in throughput but also in engineering support for recipe creation and maintenance.

The multi-layer target is a critical aspect of this project. A first pass target was printed on a test wafer by TSMC containing a third frame of 30 microns in size outside of the standard frame in frame structure. This allowed for tests to be run for feasibility. Although these tests were performed on resist to resist targets, they proved the feasibility of the program. This target had inherent limitations due to the increase in size, which could limit the placement of multiple targets on at 75 micron or less scribe line. The challenge was to design a target that would be the same size of the current ten by twenty frame in frame target. Schlumberger has designed an overlay target that does just that. A drawing of the target is presented below.

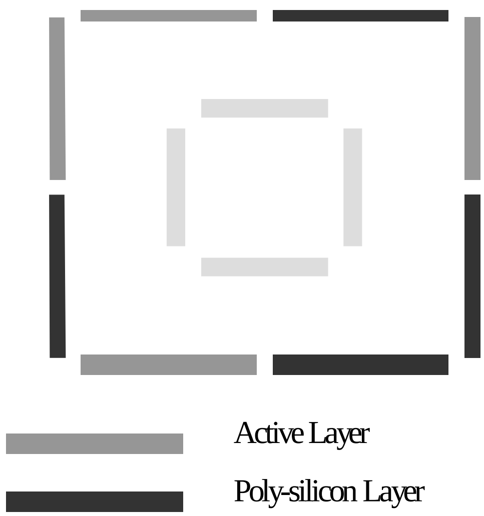


Diagram 15 – Multi-layer measurement target.

An algorithm is currently in development for the purpose of measuring the multi-layer target. The algorithm will measure the registration of all three layers at once and output the average of the two layers. It will also have the ability to output the individual components for the purpose of pass/fail criterion for both layers. The difference in timing for this algorithm versus a standard two-layer measurement will be negligible.

4. CONCLUSIONS

The active nitride to first contact and the poly-silicon to first contact overlay registration have arguably the most critical alignment requirements in TSMC FAB6's process. The data analysis above clearly shows that the multi-layer measurement allows for better process control these layers. Although TSMC is currently able to control these overlay tolerances, the process is not automated and requires engineering support, which is time that could be better, spent and can hold up the lot.

The implementation of the multi-layer feature and algorithm on TSMC's process will better control the process, allow for better corrections to the scanner when required, and also allow for better utilization of the overlay metrology tool and engineering expertise.

5. ACKNOWLEDGMENTS

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6. REFERENCES

1. B. Singh, R.M. Newcomb, J. Pellegrini, “A new paradigm for real-time stepper performance monitoring.”, Microlithography World, Autumn, 1996.