Innovative Techniques for Improving Overlay Accuracy by using DCM (device correlated metrology) targets as reference

Wei Jhe Tzai\textsuperscript{a}, Simon C. C. Hsu\textsuperscript{a}, Howard Chen\textsuperscript{a}, Charlie Chen\textsuperscript{a}, Yuan Chi Pai\textsuperscript{a}, Chun-Chi Yu\textsuperscript{a}, Chia Ching Lin\textsuperscript{a}, Tal Itzkovich\textsuperscript{b}, Lipkong Yap\textsuperscript{c}, Eran Amit\textsuperscript{b}, David Tien\textsuperscript{c}, Eros Huang\textsuperscript{d}, Kelly T. L. Kuo\textsuperscript{d}, Nuriel Amir\textsuperscript{b}

\textsuperscript{a}United Microelectronics Corp. (Taiwan); \textsuperscript{b}KLA-Tencor Israel, 1 Halavyan St. Migdal Ha’emek, 23100, Israel; \textsuperscript{c}KLA-Tencor Corp. (United States); \textsuperscript{d}KLA-Tencor Taiwan (Taiwan);

ABSTRACT

Overlay metrology performance as Total Measurement Uncertainty (TMU), design rule compatibility, device correlation \& measurement accuracy are been challenged at 2x nm node and below. Process impact on overlay metrology becoming critical, and techniques to improve measurement accuracy becomes increasingly important. In this paper, we present an innovative methodology for improving overlay accuracy.

A propriety quality metric, Qmerit, is used to identify overlay metrology measurement settings with least process impacts and reliable accuracies. Using the quality metric, an innovative calibration method, ASC (Archer Self Calibration) is then used to remove the inaccuracies. Accuracy validation can be achieved by correlation to reference overlay data from another independent metrology source such as CDSEM data collected on DCM (Device Correlated Metrology) hybrid target or electrical testing. Additionally, reference metrology can also be used to verify which measurement conditions are the most accurate. In this paper we bring an example of such use case.

1. INTRODUCTION

A propriety quality metric, Qmerit, which can be used to quantify target process imperfections, is employed to identify overlay (OVL) metrology measurement settings which are less sensitive to process impacts and most reliable accuracies. This quality metric can be used in comparative analysis for a range of overlay target designs and metrology settings, thereby, identifying good candidate combinations of target designs \& metrology settings. Results accuracy of each target designs and metrology settings is then verified by CDSEM data collected on DCM (Device Correlated Metrology) hybrid target. Furthermore, simulation of light spectrum behavior per target geometry and film stack information also supports target designs \& metrology settings selection based on anticipated precision.

Using the quality metric results (Qmerit), an innovative calibration method ASC (Archer Self Calibration) is used to remove the inaccuracies. Using the measurement information from various target or metrology settings, the calibration methodology estimate the inaccuracies and calibrate the overlay data to most accurate behavior. This in turn, results in significant improvement in correlation to reference CDSEM data measured on DCM target for all available targets and metrology settings combinations.

Both the quality metric and calibration methodology are designed to be on-the-fly applications that do not affect measurement time, making it optimized for production environment.

In this study we investigated the inaccuracy factors and its influence on measurement results. By measuring DCM Hybrid OVL target with both Archer and CDSEM tools and compare the results, we were able to estimate which condition is the most accurate one.
2. Overlay Inaccuracy

2.1 Process induced asymmetry and influence on OVL results

Reference layer target pattern, especially of critical layers, are often subject to etch, polish and further thin film deposition. All of the above can contribute to target asymmetry as illustrated in figure 1.

Asymmetric slop caused by etch process is illustrated in Figure 1a. Etch induced asymmetry is caused by the non-uniform plasma destitution across the wafer and therefore has radial behavior and appears as additional expansion term at OVL measurements.

Asymmetric trench caused by polish process is illustrated in figure 1b. At CMP (Chemical-Mechanical Polish) process, wafer is been pressed and rotated on a polish pad, in specific direction. Incase large area is filled with softer material then the surrounded material, the softer material undergo dishing, and since the wafer is rotated the dishing profile might be asymmetric. CMP induced asymmetry appear as translation term on the wafer at OVL measurements, while the translation vector follow the CMP rotation direction, as shown in figure 2.

Asymmetric layer deposition caused by CVD deposition, as illustrated in figure 1c, is caused by the nature of PECVD (plasma enhance chemical vapor deposition) at wafer edge. Trench fill induced asymmetry has radial behavior and appears as negative expansion term at OVL measurements (opposite to etch behavior).

Need to mention that these process induced asymmetries can be addressed by optimal target design, which mimic device geometry and density. For example, segmentation of large features and placing dummy patterns at open areas.

Estimation of the asymmetry influence on OVL accuracy was done by simulation. In the simulation, we simulated AIM target with zero induced OVL, but with induced asymmetry, as describe in figure 3a. The value of the right angle was fixed on 90°, while the left angle value was modify between 90°, 98° & 106° (need to mention that these values are not typical, and usually smaller, however, we used these value to emphasis the influence). Results presented in figure 3b, show that OVL inaccuracy increase as sidewall angle asymmetry increased. Interesting observation from this simulation is that OVL inaccuracy strongly depends on the wavelength used for measurements, and some wavelength. This was part of the motivation for having an independent reference metrology (hence CDSEM) to validate which measurement conditions should be used. In this simulation, wavelength of 500nm was found to be not sensitive to target asymmetry.
2.2 Using Qmerit to estimate process asymmetry

When using imaging base method, OVL can be extract using several signal processing algorithms. When target is perfectly symmetric, all algorithms will report the same OVL value. However, if the signal has a build in asymmetry, as was acquired from the target image, the different algorithm will report different OVL values. Qmerit value represent the distribution of the OVL values through the different algorithms. Using Qmerit values we are able to identify target which was damaged by process and therefore induced asymmetry and additionally identify which process condition (for example color filter) is less sensitive to the process variation, as describe in the simulation in 2.1, where different WL show different sensitivity to process variations. For more details please see reference number 3.

Qmerit tool can be used for choosing optimal color filter, which has the lowest sensitivity to target asymmetry, and eventually contribute to measurement robustness.

2.2 ASC – Archer Self Calibration

Using the Qmerit results, an innovative calibration method ASC (Archer Self Calibration) is used to remove the inaccuracies. Using the measurement information from various target/metrology settings, the calibration methodology estimate the inaccuracies and calibrate the overlay data to most accurate behavior. For more information please see reference number 2.

2.3 DCM hybrid target

DCM hybrid target enable OVL measurement using CDSEM, on same actual pattern which is measured at Archer OVL measurements verification. Figure 4a show schematic drawing of imaging OVL target of type AIM (Advance Imaging Metrology) where each bar is segmented into several lines with fin CD. The previous layer lines lay in-between current layer lines which enable, after etch and strip process are done, to measure the OVL between them. This measurement is only possible for cases where both previous and current layers are visible at top view and measurable by CD-SEM. In Figure 5b OVL between Poly and Isolation layers was measured.

Since both metrology methods are measured on same location, the comparison is done on pattern which has undergo same process conditions and apply same OVL shift.

Figure 3: Simulation of etch induced asymmetry impact on OVL. (a) Simulated target geometry. (b) Simulation results of OVL inaccuracy vs. asymmetric sidewall angle.
3. Results and discussion

3.1 Qmerit results

As discussed in the process induced asymmetry part, we have found that different WL show different sensitivity to asymmetry in the measured pattern. Therefore it requires having a method which enables to select the WL for measurement that will have the lowest sensitivity. As shown in Figure 6, different WL filters show different Qmerit values, where blue is the one with lowest deviation, which makes it the best candidate for OVL measurement setup.

Two interesting observations can be seen from Qmerit results. First one, the best two color filters within the spectrum are blue and NIR which positioned on both edges of the spectrum. Second one, when looking at the results through the spectrum, a structural trend can be observed, but with distortions at the wide band color filters (ivory, white & WNIR). The possible reason is that within wide spectrum color filters, several WL responses differently to the geometry and may compensate, or average, the geometry influence.
3.2 DCM hybrid target – results of OVL correlation to CDSEM

CDSEM OVL measurements were done on DCM “Fingure AIM” target, after etch process using Hitachi HHT, CDSEM **CG4100** High performance CD-SEM tool. Measurement set-up was as described in section 2.3, and results are shown in figure 7, for three color filters which had the best correlation, blue, green and ivory, where blue color filter show the best results.

![Graph](image)

Figure 7: (a), (b) Correlation between Archer OVL and CDSEM OVL for X and Y respectively. (c), (d) Correlation parameters (linear fit)
3.3 ASC calibrated data

ASC algorithm was apply on the Archer OVL data, when alpha was calculated using OVL data collected by three color filters, blue, green & Ivory. As a result, CDSEM correlation was significantly improved after ASC calibration, for all color filters, as can see in figure 8.

![ASC calibrated data](image)

### ASC algorithm

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### ASC algorithm parameters

<table>
<thead>
<tr>
<th>Color Filter</th>
<th>Correlation $R^2$</th>
<th>Slope</th>
<th>Intercept</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blue</td>
<td>0.96</td>
<td>-1.12</td>
<td>0.05</td>
</tr>
<tr>
<td>Green</td>
<td>0.95</td>
<td>-1.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Ivory</td>
<td>0.90</td>
<td>-0.93</td>
<td>0.34</td>
</tr>
</tbody>
</table>

![ASC algorithm parameters](image)

3.3 Imaging simulation results

Imaging simulation is done by building Johns matrix for the whole stack using RCWA algorithm and then apply all wavelength within Archer measurement spectrum on the matrix in order to estimate what will the contrast of the measured feature. In the investigated case, imaging simulation results show blue color filter is the best measurement setup since the kernel profile at short wavelengths had the highest contrast of the target pattern (yellow lines are trenches of Oxide within Si substrate), and by that gave additional confirmation for blue as the preferred candidate. Figure 9 shows the stack kernel profile of both previous and current and.

![Imaging simulation results](image)

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4. Summary

In this paper we have demonstrated how OVL measurement accuracy can be improved by using Qmerit and ASC algorithm and verify accuracy by reference metrology, using DCM hybrid target. Results have shown that all method, Qmerit, CDSEM and imaging simulation are converging into one conclusion, that blue wavelength filter is the most accurate candidate for measurement setup of this layer. Using ASC, we are able to use other wavelength filters, by calibration the data.

Currently, OVL measurements using CDSEM are only possible when both measured layer are apparent on the wafer surface, which limited this method for specific layers, however, using de-cup, which etch the layer that cover the required layer, we are able to measure these layers as well.

REFERENCES