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Scatterometry or Imaging Overlay
a Comparative Study

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Keywords: Overlay, Accuracy, process robustness, IBO, SCOL, DBO, uDBO

1. INTRODUCTION

Most fabrication facilities today use imaging overlay technology, as it has been the industry's reliable workhorse for decades. In the last few years, third-generation Scatterometry Overlay (SCOL™) technology with pupil access (DBO-1) was developed, along another DBO technology without pupil access (DBO-2). This development led to the question of where DBO should be implemented for overlay measurements. DBO has been adopted for high volume production in only few cases, always with imaging as a backup, but scatterometry overlay is considered by many as the technology of the future. As we can see in Figure 1, the Overlay budget which is composed of the OVL 3 sigma is decreasing every year according to ITRS roadmap [1]. This means that the margin for the error of the overlay measurements needs to decrease accordingly. Specifically we can see that today every single nm counts.

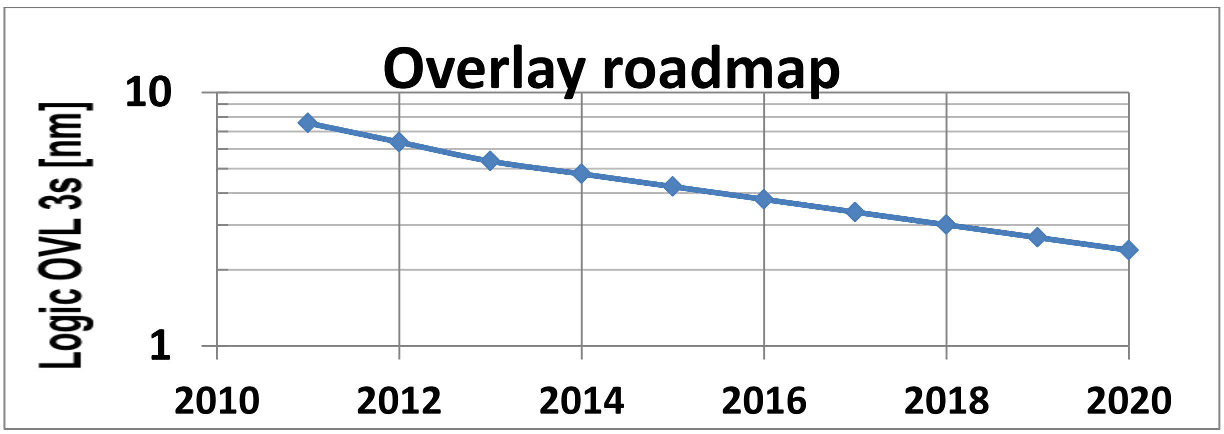

Figure 1: ITRS Logic/MPU Overlay roadmap per year is trending down logarithmically to support Moore's law[1].

2. EXPERIMENTAL RESULTS

As can be seen in Table 1, the experimental results of this study encompass ten layers of the advanced node process. This study was conducted during a period of about nine months so in the development node many process changes occurred and obviously the process variation was still not as stable as production. Results show that DBO-1 technology was mature and able to deliver results satisfying the spec. DBO-2 was not able to meet all the specs, most specifically it had problems measuring poly to SN (Isolation) layers. We will show here results for one layer for which the most extensive study was done, including measurements with all techniques: DBO-1, imaging, DBO-2 and reference OVL testing described in our previous work [2]. Another layer, for which results will be presented, is Poly to SN, which is one of the most difficult layers for Overlay measurements. Poly to SN was measurable with imaging and DBO-1, but not with DBO-2.

Layers			DBO-1 Av. TMU [nm]	Imaging Av. TMU [nm]	DBO-1 residuals divided by imaging residuals [A.U.]	
					X	Y
Advanced Develop. Node	1	BEOL	0.205	0.5	0.94	0.92
	2		0.16	0.47	0.85	1.03
	4	FEOL	0.37	0.64	0.44	0.72
	5		0.72	0.71	0.43	0.43
	8	MEOL	0.2	—	0.89	0.69
	9		0.225	—	0.50	0.51
Prod. Node	11	MEOL	0.16	—	0.95	1.06
	13		0.205	0.48	0.99	0.97

Table 1: Partial list of the layers participating in the study. Due to confidentiality, the DBO-1 residual data shown is normalized by the imaging residuals, so values smaller than 1 mean DBO-1 is better. Imaging TMU was collected only for part of the layers.

The DBO-1 overlay values were well matched to the POR imaging results (slope $\geq$ 0.98, $R^2 \geq 0.97$) as can be seen in the data in Figure 2, and by Side by Side matching (SBS) average of X and Y ~1.1 nm in Table 2. This kind of matching can more easily be done on a tool having both imaging and DBO-1 technologies as the Archer 500LCM. This is one of the advantages of such a tool, showing a use case critical for quickly assessing recipes consistency, one technology is the ruler for the other technology. When both technologies show consistent data, one can be more confident that the measurements can be trusted. This consistency check is quick, easy to do and it provides confidence in the results, since in most cases inaccuracy sources impact the two methods differently. If one technology is biased due to some process instability interaction, the other technology will not be biased in the same way or quantity, so the results will not be consistent. This allows checking the consistency even during production without an external ruler. For the sake of completion we state that the other scatterometry technology DBO-2, for the layers it was able to measure, also was correlated with imaging in most cases. For this layer, the R^2=0.98 is good, but the slop is only 0.9 as seen in Fig 2. SBS matching with imaging as seen in table 2 is good at ~1.05 nm sigma and correctables matching is good except expansion, which may lead up to 1.5 nm mismatch at the wafer edge, as seen in table 3 and figure 3 (multiply the expansion value by 150mm to get the wafer edge value). DBO-2 matching to DBO-1 is not perfect and is similar to the level of matching of DBO-2 to imaging.

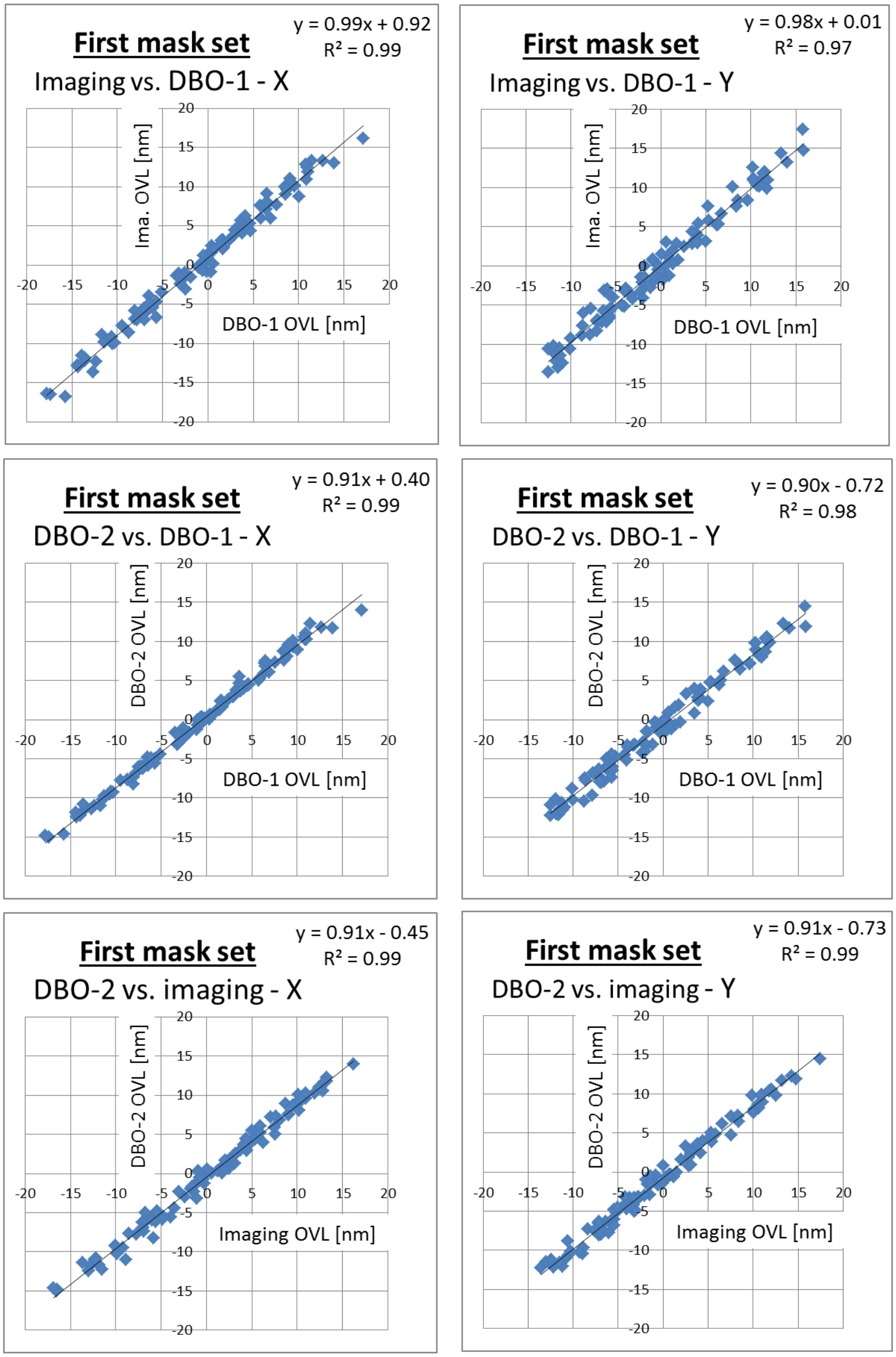

Figure 2: for the first mask set, Comparing DBO and imaging showing excellent correlation: R^2>0.97 and slope of 0.90-0.98. DBO-2 is well correlated to both DBO-1 and imaging but the slop is at only ~0.91

3. ACCURACY VERIFICATION

The OVL data from the same two mask sets analyzed in the previous section was also checked versus an external ruler of reference OVL described in our previous work [2]. See also some more of our work on accuracy [3-8]. Though just looking at the results of Figures 2-3 and tables 2-4, one can clearly see that using one technology as a ruler for the other indicates they are both well correlated, which is an indication for accuracy. Still, we decided to verify the accuracy with an external ruler.

In Figure 3 and Table 4, we can clearly see that Both DBO-1 and Imaging are very well correlated to the reference OVL with R^2 >0.96 and slopes >0.95. SBS data shown at table 2, indicates DBO-1 is well correlated to all other measurement technologies; especially it is best correlated to reference OVL at SBS sigma average of only about 1nm. Imaging and DBO-2 are similarly correlated SBS to reference OVL with sigma of about 1.4-1.5 nm. DBO-2 has also good R^2 >0.97 but the slope is a bit off at about 0.88, consistent with Fig 2 were imaging was used as the baseline. As is well known, slope different than 1 indicates an expansion term offset, causing inaccuracy at the wafer edges. In Table 3 and figure 3, we can see evidence exactly for that, the expansion of DBO-2 is different than that of the rest of the measurements techniques: DBO-1, imaging and reference OVL.

First mask set: Sigma of SBS differences of optical measurements vs. reference OVL [nm]		
	X	Y
DBO-1 vs. reference	1.13	0.87
Imaging vs. reference	1.44	1.51
DBO-2 vs. reference	1.42	1.41

First mask set: Sigma of SBS differences of optical measurements vs. each other [nm]		
	X	Y
DBO-1v s. imaging	0.91	1.22
DBO-1 vs. DBO-2	0.94	1.18
DBO-2 vs. imaging	1.05	1.04

Table 2: this data, collected for the first mask set, shows the Side By Side (SBS) differences between all measurements and reference OVL (2a) and between all measurements technologies and themselves (2b).

Model Terms	Ref. OVL	DBO-1	DBO-2	IBO
X_Tran (um)	-0.0009	0	-0.0003	-0.0006
Y_Tran (um)	0.0009	0.0008	0.0001	0.0007
X_Exp (ppm)	0.1044	0.1051	0.101	0.1074
Y_Exp (ppm)	0.1042	0.1035	0.0942	0.104
Rot (urd)	0.0177	0.0172	0.0175	0.0182
N_Ortho (urd)	0.0048	0.0034	0.0019	0.0026

Table 3: First mask set correctable terms showing matching. DBO-2 expansion is somewhat shifted.

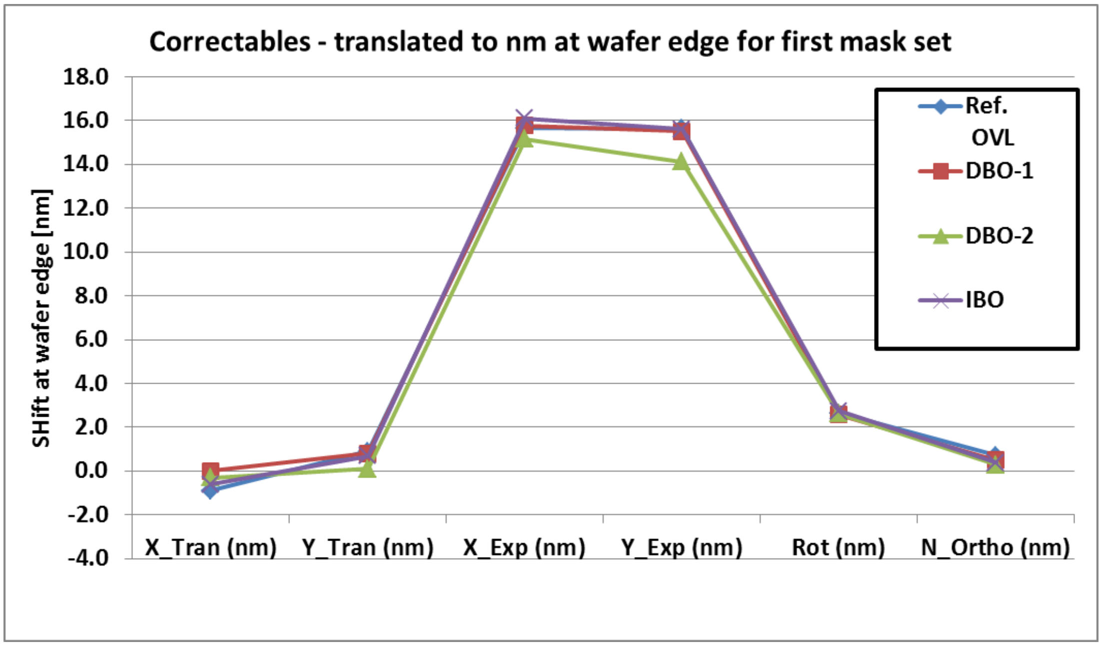

Figure 3: First mask set correctable terms showing matching. DBO-2 expansion is somewhat shifted.

Correlation to reference metrology [A.U.]		
	Slope	R^2
DBO-1 X	0.97	0.98
DBO-1 Y	0.98	0.99
Imaging X	0.95	0.97
Imaging Y	0.96	0.96
DBO-2 X	0.88	0.98
DBO-2 Y	0.89	0.97

Table 4: For the first mask set: accuracy results indicated by comparing to an external ruler With DBO-1, Imaging and DBO-2. All have excellent R2 >0.96. Note the slopes of DBO-1 & imaging >0.95

4. INDUSTRY BENCHMARK RESULTS

This study results match the industry wide experience summarized in Table 6. The table represents the results of this study combined with more industry experience.

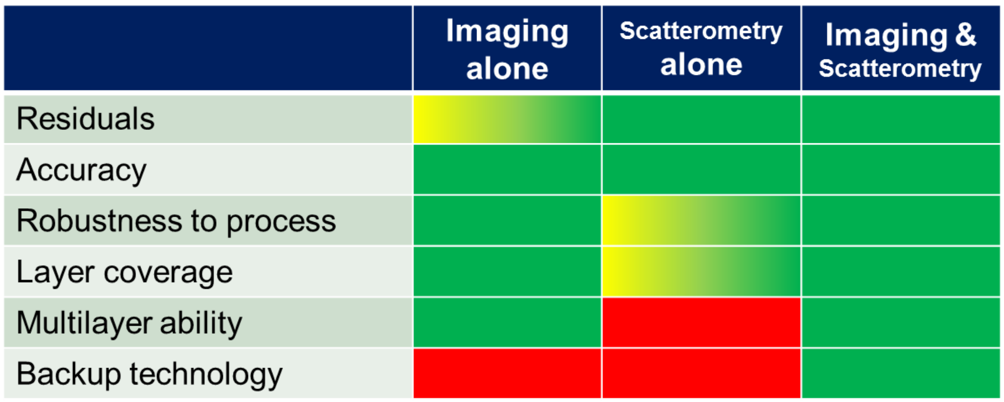

Table 6: Benchmarking Overlay technologies; Imaging versus Scatterometry vs both together.

5. SUMMARY

In this study, two types of overlay technologies were compared: imaging and scatterometry. The scatterometry technology was represented by two variations: DBO-1 (SCOL) and another DBO. The process and layers used are ten advanced development node layers as well as three production layers. We conclude that both imaging and DBO-1 technology are successful and have a valid roadmap for the next few process nodes. Both imaging and DBO can potentially provide good accuracy, TMU and residuals in spec. In DBO-1 technology which is “TIS less” results have lower TIS and thus better TMU in most cases; it also has lower residuals in many cases. This work was combined with an industry benchmark showing the main advantages of imaging are simplicity of set up and troubleshooting, process robustness and being a baseline backup technology. DBO-1 technology tools used in this study are Archer 500LCM which have both imaging and DBO-1 on the same tool. This unique tool option allows a simple backup of DBO with imaging and vice-versa and a simple use of one technology as a ruler for the other. Having both options available in parallel, allows Overlay engineers a mix and match overlay measurement strategy, controlled transition to DBO, providing back up when encountering difficulties with one of the technologies and benefiting from the best of both technologies for every use case.

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