

Physical Matching vs CD Matching for CD SEM

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ABSTRACT

CD-SEMs fleet matching is a widely discussed subject and various approaches and procedures to determine it were described in the literature. The different approaches for matching are all based on statistical treatment of CD measurements that are performed on dedicated test structures. The test structures are a limited finite set of features, thus the matching results should be treated as valid only for the specific defined set of test features. The credibility of the matching should be in question for different layers and specifically production layers. Since matching is crucial for reliable process monitoring by a fleet of CD-SEMs, the current matching approaches (such as TMU) must be extended so that the matching will be only tool dependent and reproducible on all layers regardless their specific material or topographic characteristics. In this work the term "Physical Matching" is introduced and a new matching procedure based on physical parameters is described. This approach extends the conventional matching methods to enable significant improvement of the matching between CD-SEM tools in production environment. To study and demonstrate the physical matching, we focus on limited parameters set - the image brightness and Signal/Noise ratio (SNR). We test the sensitivity of CD measurements to changes in these parameters both on different test layers – Etch and Litho. We show that sensitivity of CD based measurements is low and reasonable change of the image brightness or SNR has small effect. The advantage of the physical matching approach for case study is demonstrated. The improved matching procedures are based on new targets that are used to measure the above image parameters directly. This way it is possible to characterize correctly the physical state of the measurement tool and guarantee the same image characteristics which in turn guarantee improved matching on all layers. In the framework of the proposed matching approach a proper determination of the minimal set of physical parameters that is needed to guarantee CD-SEM tools stability and matching should be included. The proposed procedure allows fixing tool problems before CD measurements are affected.

Keywords: CD SEM, SEM Metrology, tool matching, fleet matching, CD, TMP, FMP

1. INTRODUCTION

1.1 Fleet Tool Matching as a modern industry challenge

The problem of fleet tool matching has been relevant for using of CD SEM as metrology tool in production for every technological node age (see, for example, the early paper [5]). The comprehensive review of metrology fleet tool management that includes requirements, modern approaches for tool matching and problems definition was done in [1]. The standard approach to fleet tool matching is based on a sophisticated procedure that includes measurements, comprehensive data collection, storage and analysis. This approach was described in details in [1,3]. The definition of tool matching following this work is an “assuring measurement matching across fleet of tools”. The author underlines the importance of tool calibration across a fleet of tools as a condition of proper recipe running. The measurement requirements for modern technology nodes are defined in the International Roadmap for Semiconductors (ITRS) [2]. These requirements define matching as an integral part of precision specification for metrology tools. ITRS points out the demands of tool’s stability and calibration as a prerequisite for accurate CD metrology. Quantitative metrics providing fleet matching management were developed and described in [3, 4]:

- a) Fleet Measurement Precision (FMP) – a metrics that allows to describe a fleet tool performance by one number in units of length(*nm*);

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- b) Tool Matching Precision (TMP) – a metrics that describes single tool performance relative to reference system named Benchmark Measurement System (BMS). BMS can be or either reference (“Golden”) tool or fleet average.

The estimations of fleet matching influence on potential capital loss demonstrate great economical value of any improvement of fleet matching metrics [1]. The next important matching factor defined in [1] is a Portability Matching. The Portability Matching was defined as understanding, monitoring and reducing of the tool contributors affecting recipe run across the tools fleet. Several factors can affect Portability Matching – navigation accuracy, image acquisition conditions, system noise level, detector gain and so on. Examples of Portability Matching monitoring include Stage Navigation Monitoring and Gate centering monitoring. In the present work the strategy of Portability Matching is extended to monitoring of SEM image acquisition. The Physical targets corresponding to detector gain and noise level monitoring procedures are defined and investigated.

1.2 Regular approach to fleet matching monitoring – CD Matching

Fulfillment of the Fleet Matching Management procedures requires definition of a new metric that can be used for quantitative description of specific tool or fleet tool state. A detailed description of matching metrics was done in [3]. The authors succeeded in defining FMP and TMP precision metrics as exact mathematical statistical procedures based on CD measurements, that is precision recipes running on the tools. The sophisticated statistical procedures for new metrics calculation are based on Mandel analysis [3]. These metrics are defined in units of length, i.e. in nanometers and allow simple comparison with ITRS requirements to precision [2]. The tool offset, non-linearity and precision are taken into account as contributors to matching metrics and can be considered separately. The most important problem that was considered by the authors is the beam interaction with sample which causes shrinkage, carbonization and charging. These material related effects require specific treatment in statistical procedures. Corresponding procedures (carryover-free precision estimations) are based on reduction of linear trend in the case of carbonization or non-linear trend for resist layers CD measurements.

1.3 Limitations and challenges of approach to tool matching based on CD measurements

In [3] the correlation between FMP metrics based on CD measurements and CD SEM tool physical parameters was described. We can define roughly the main contributors to FMP as offset term, precision term and non-linearity term. A thorough analysis of every term by experienced user allows finding the Root Cause of matching problem. For example, the offset term (offset equals to difference in average CD measurements between tools) can be related with magnification calibration problem, electron beam spot size, stray tilt and stigmatism. Precision term should lead to SEM tool noise investigation. The non-linearity term can reveal problems of scan linearity and detector sensitivity. Here we observe the non-unique correspondence between the matching metrics and tool physical and technological parameters that we name State Variables. We see that many State Variables can influence the same measured matching metrics or metrics contributor.

Another problem that can be defined is Process or Layer dependency. It means that any matching metrics or specifications for one production layer or feature do not guarantee the same matching number for other layer or feature. Therefore there is a need to perform the matching process on different layers and different targets – this can result in increasing the time needed for Root Cause Analysis(RCA). For example, the verification of matching metrics in [3] was done for six production layers and few targets for every layer. As a result, the matching procedures time includes the multiple recipe runs, statistical analysis of measurement and RCA treatment increases significantly.

Another challenge is related to automation of Root Cause Analysis procedure. The ANOVA statistical approach to Root Cause Analysis of matching problem was described in [5, 6]. In the framework of this approach it is possible to provide a coarse analysis of the fleet matching situation or separate tools to “well matched” and “poorly matched” groups.

The next challenge is related to the matching of CD SEM tools produced by different vendors. This problem was considered in [7]. The authors described the influence of physical parameters such as signal to noise ratio, scan linearity and scan magnification on the CD measurements. The difference in the process window definition related to the different physical parameters of the CD SEMs produced by different vendors illustrates the possible problem caused to the bad matching between fleet tools of the same vendor (see Fig.6 in [7]). Authors concluded that adjustment of physical parameters of different CD SEMs can be done and a proper matching between CD SEMs from different vendors can be achieved.

1.4 Monitoring of Physical Parameters of CD SEM Tool as a way for Tool Matching improvement

The many attempts to improve matching through development of novel procedures for monitoring of CD SEM tool physical parameters are described in literature. A comprehensive description of the Stray Tilt calibration procedure that can be associated with our approach was done in [4]. The introduction of Image Quality Monitor (IQM) utility as a way of tool matching enhancement was proposed in [8]. The usage of IQM includes principal possibility to measure and follow up on the image acquisition metrics associated with human eye perception of image quality- resolution, signal to noise ratio (SNR) and contrast to noise ratio (CNR). The authors demonstrated good sensitivity of the developed metrics to the correspondent physical factors and verified the utility performance on simulation (Monte-Carlo SEM images) and real SEM images. The direct relation between industry standard of CD SEM image quality metrics such as apparent beam width (ABW) was demonstrated. The Fourier-transform analysis based approach with using specially fabricated test sample was considered in [9, 10]. The authors demonstrated principal possibility of accurate follow up on the resolution of CD SEM microscope with this technique that straightforward allow to improve the resolution contributor to fleet matching metrics and follow up for such physical parameter as beam width. An operator independent technique for beam size measuring (BEAMETR) was introduced in [10]. This technique is based on a reference sample pattern that can be installed into any SEM. After the image is scanned, the software application analyzes spatial frequencies of the pattern and automatically determines the beam size. The method is based on a comparison of spatial characteristics of a specially designed pattern and its image, which involves information about beam. As a result, the capability to follow up for beam size with high accuracy could significantly improve tool to tool matching metrics. The problem of multiple CD SEM matching at different exposure conditions was considered in [11]. The authors considered the CD SEM stability issue as a part of matching problem. The application procedure providing matching of such physical factor as magnification through pitch calibration was described in detail. The modern requirements and challenges to CD SEM matching are related to intensive usage of CD SEM for Optical Proximity Correction (OPC) verifications [12]. The principal challenge of manufacturing is related to large CD variations across a process node. The authors considered the combination of different methods of matching as a strategy to get the best fleet matching. The methods include hardware optimization, application optimization, statistical methods for CD data analysis, sampling optimization and monitoring optimization. The hardware factors affecting matching include Stray Tilt, Measurement Box Placement deviations and image conditioning (brightness, contrast, SNR). The authors pointed out on the critical importance of tool monitoring and described the solution based on dedicated Matching-Maintenance-Monitoring (M^3) server. The authors demonstrated the great sensitivity of daily monitoring approach to physical changing in tool functionality. The CD SEM Resolution Monitoring application based on Apparent Beam Width (ABW) artifact is described in [13]. This target is closely related to another resolution targets considered in [8, 10]. The possibility to use special ABW target in matching application is considered. A comprehensive investigation of the influence of system noise and beam size on repeatability and bias of CD SEM measurements in simulation experiments was presented in [17]. The correlation between image acquisition parameters and CD measurements was demonstrated. The authors underlined the importance of investigation of influence of tool parameters on metrology results in real CD SEM experiments. Summarizing the introduction, we can state that monitoring of physical parameters of the measurement tool is recognized in industry as an important part of fleet tool matching.

2. METHODOLOGY

2.1 Physical Matching – general description

Let's introduce definition of Physical Matching. We define the "Physical Matching" as the direct measurement, monitoring and analyzing of CD SEM physical parameters for improving the matching between tools. To study and demonstrate the Physical Matching concept, we propose to focus on limited parameters set - the image brightness and signal to noise ratio (SNR). We propose to test the sensitivity of CD measurements to the changes occurring in these parameters on different layers – Etch and Litho. We demonstrate the advantage of the physical matching approach in case study. The improved matching procedures are based on new targets – Gray Level Target and Noise Monitoring Target. This way it is possible to characterize correctly the physical state of the measurement tool and guarantee the same image characteristics which in turn guarantee improved matching on all layers. In the framework of the proposed matching approach a proper determination of the minimal set of physical parameters that is needed to guarantee CD-SEM tools stability and matching should be performed. Despite the relatively small changes in CD values observed for test layers for reasonable SEM image brightness and noise changing, these effects should be taken into account for

aggressively tight 32-45 nm nodes ITRS specifications. The essence of the proposal is to improve matching tool procedure by development of “Physical Targets” that allow monitoring of image formation process and provide effective feedback control and machine state monitoring. We assume that any physical target dedicated to the direct measurement of specific physical parameter will be more sensitive to this parameter than indirect CD metrics (using CD targets) that are accepted as standard targets for matching procedure and CD SEM tools state monitoring in industry.

2.2. Gray Level Target definition

Using common sense, one can assume that two CD SEM tools with same image brightness for the same image of the same feature will be matched better than tools with different brightness. We can consider the Gray Level Target as the simplest Physical Target designed for image brightness monitoring. Let's consider a SEM image of the feature as a matrix

$$\text{Im}(i, j) \quad (1),$$

where $\text{Im}(i, j)$ is a gray level at the location (i, j) . The average gray level GL is defined as

$$GL = 1/n \sum_{i,j} \text{Im}(i, j) \quad (2),$$

where n is a number of pixels of the image. The calculation of GL can be considered as a measurement of the CD SEM tool physical parameter- image brightness([14]), that can be performed on any CD SEM image during daily monitoring of image acquisition stability. We can assume that a typical SEM image is consisted from three regions – background, feature edges and feature area. That allows replacing the scalar metrics GL in Equation (2) with the vector metrics \overline{GL} :

$$\overline{GL} = \{GL_{\text{Background}}, GL_{\text{Edge}}, GL_{\text{Feature area}}\}, \quad (3)$$

where every component's value is defined by Equation (2) for specific image region. The procedure of monitoring of the vector value of image brightness is similar to monitoring the Top, Bottom and Main Slope CD measurements for process window control. The important point is that measurement of brightness can be done simultaneously with CD measurements during daily tool monitoring and does not increase tool maintenance time. The physical parameter of CD SEM tool that directly related to this metrics is the detector gain, and this target can be also named as “Detector Gain Target”. The advantage of vector metrics \overline{GL} on scalar GL for RCA will be demonstrated in further.

2.3. Noise Monitoring Target definition

Similarly to the effect of image brightness on the CD measurement, one can assume that two CD SEM tools with the same images of the same features and with the same noise variance should be matched better than tools with different noise variances. We define Noise Monitoring Target as the simplest physical target designed for image noise variance monitoring. The optimal data for noise measurement is a bare image – where the average gray scale is the image signal, and the noise is the variance of the image. In this case the measure of image noise $STD(noise)$ is done by the standard deviation ([14]):

$$STD(noise) = \sqrt{\frac{1}{n} \sum_{i,j} \text{Im}(i, j)^2 - \left(\frac{1}{n} \sum_{i,j} \text{Im}(i, j) \right)^2}. \quad (4)$$

The calculation of $STD(noise)$ can be considered as a measurement of physical parameter- image noise variance that can be performed on any SEM image for monitoring the image acquisition stability. It is important to notice that given same average gray level, the estimation is correct, as noise is considered to be intensity dependent. Therefore, calculating of the noise variance should be performed only after establishing of same gray levels for images of the same target from

different tools. It can be assumed that a regular SEM image is composed from three regions – background, feature edges and feature area. We can assume that background area is not sensitive to the feature texture related noise. Therefore the image noise should be calculated only on the background region – where the signal is the average gray level and the variance in the gray level of the image is due to noise. That gives

$$STD(noise) = \sqrt{\frac{1}{n} \sum_{i,j} Im(i,j)^2 - \left(\frac{1}{n} \sum_{i,j} Im(i,j) \right)^2}, \quad (5)$$

$\forall i, j : Im(i, j) \in Background.$

This procedure can be performed by extraction of the image edges and performing segmentation. The noise *STD* is calculated only on the background region. Similar analysis can be performed on the feature area, as long as texture is not part of the feature area. The procedure for calculating and monitoring the noise variance of an image can be done after the feature's edges locations are extracted and the locations of the background, feature edges and feature area are known. This can be done as a part of CD measurement algorithm for process window control. The important point is that measurement of noise variance can be done simultaneously with CD measurements for daily tool monitoring and has negligible influence on the throughput. The physical parameter of tool directly related to this metrics is the image acquisition noise, and this target can be named also “Noise Monitoring Target”.

2.4. Root Cause Analysis methodology

The problem defined in this methodology is: given inputs of image brightness and signal to noise ratio (SNR), one should give the answer of whether or not a problem occurred on the monitored tool and what the root cause of this problem is. This could be reduced to a classification problem, where the input is the physical parameters, and the output is the root cause. There are many standard classification methods to solve this problem, among them: Fuzzy decision trees, Neural Networks, Nearest-Neighbor Classifier, etc. [15, 16]. The simplest option is to use a-priori data and creating probability decision trees based on specialist experience – that is setting certain threshold (average and variance) on the monitored parameters drift to catch exceptions on those parameters. Using this option will yield a classifier that classifies without training, though it still can be updated on the fly with information that is gathered during its activation. Other methods require a large data set of classified examples that should be acquired during working with tools in various calibration scenarios – thus representing the different states of the tool. After this data is gathered – the classifier training is performed and created. After this stage, at the next iteration when a new input vector is given – the state of the tool is classified.

3. RESULTS

3.1 Gray Level Target feasibility study

3.1.1 Simulation study

At first, we present results of simulation of image brightness changing on CD measurements. Our purpose was to estimate an influence of image brightness changing related to Physical parameter - detector gain on CD measurements (See Figures 1,2). We found that due to high robustness of CD Measurement algorithm for specific layers, a strong changing of brightness that can affect tool matching on other layers can not be tracked by CD measurements. In the Figure 2 we demonstrate results of verification of Gray Level Target concept in simulation experiment. From comparison of Figure 2a) and Figure 2b) we conclude that Gray Level Target measurements are much more sensitive to image brightness changing than the CD measurements.

We found that changing of CD in region 1-3(Gray Level in arbitrary units in the simulation example, Figure 2) has the same order as a precision of CD measurements (<0.5 nm) and does not reflect changing of image acquisition conditions that can be observed visually(See Figure 1a)-1d) and Figure 2a). The results of Gray Level target (GL) measurements (Figure 2b) in the same region are much more sensitive (50% changing!) and can be used for monitoring of related CD SEM physical parameter - detector gain.

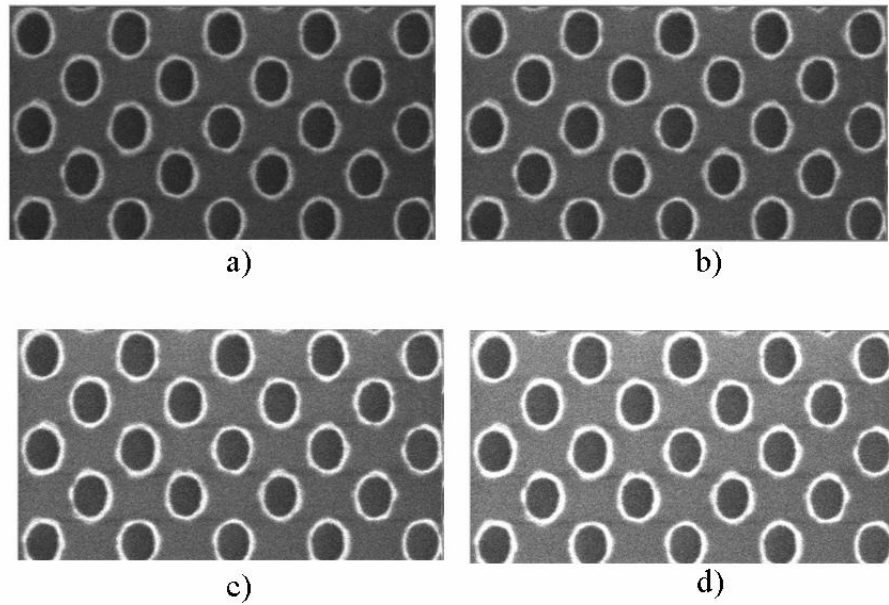


Figure 1a)-d). CD Targets with different brightness (Simulation in Matlab).

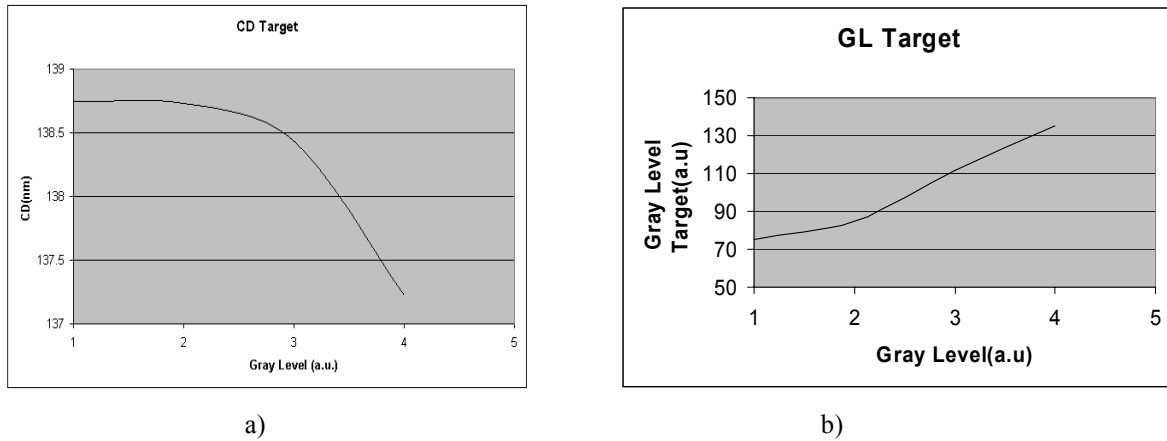


Figure 2a-b). Verification of the Gray Level Target in Matlab simulation experiment: a) Results of CD measurements (CH bottom diameter) on the images from Figure 1a)-d); b) Results of Gray Level Target measurements of the same images; a.u.-arbitrary units

3.1.2 Gray Level (GL) target verification on the tool

Next, we present results of verification of influence of detector gain changing on CD measurements on the CD SEM tool. We performed verification of the Gray Level Target concept for contacts and line targets for Etch and Resist test wafers. The results confirm predictions of simulation experiments (See Figure 4a), b) vs. Figure 2a), b)). We observe relatively small changing of CD ($< 0.5 \text{ nm}$) for reasonable changing of detector gain (for 50%-150% range -100% corresponds to nominal value of Detector Gain). We should underline that, despite small values of these changing, we can not neglect these effects for 32-45nm nodes ITRS specifications requirements. The experiments on the tool demonstrate that influence of the physical parameter changing is different for different layers (Figure 4a and Figure 5a).

At the next stage we verified GL target performance on the tool for different layers (Etch and Resist) and different CD targets (contacts and lines). We simulate the changing of image acquisition conditions through calibration of detector gain (Figure 3). After acquisition of images we compare results of CD and GL targets (See Figures 4a)-4b and 5a), b)).

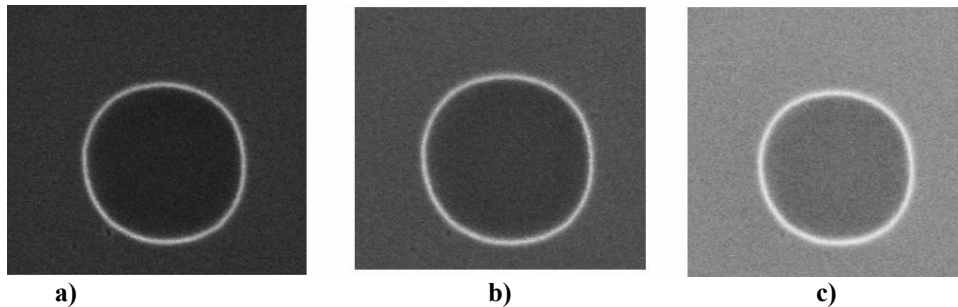


Figure 3a)-c). CD Targets with different brightness (detector gain) from the CD SEM tool.

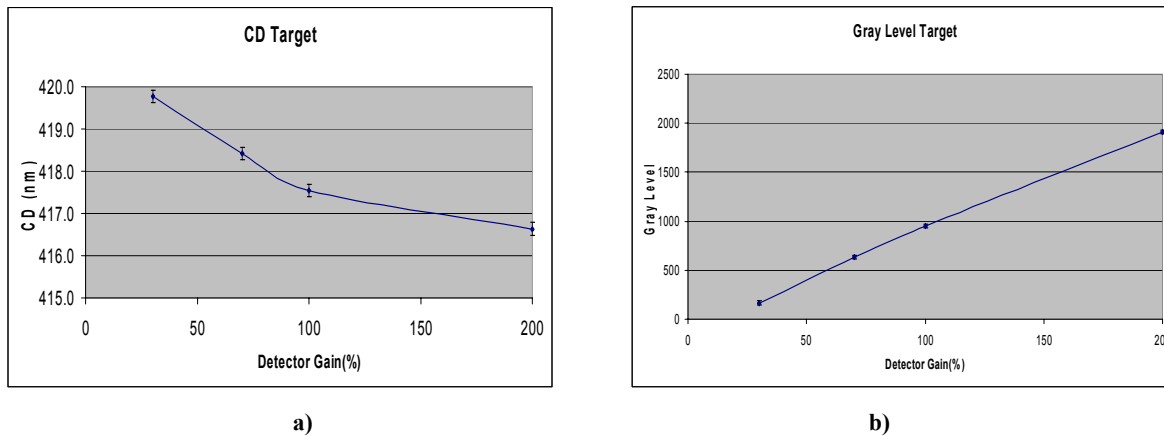
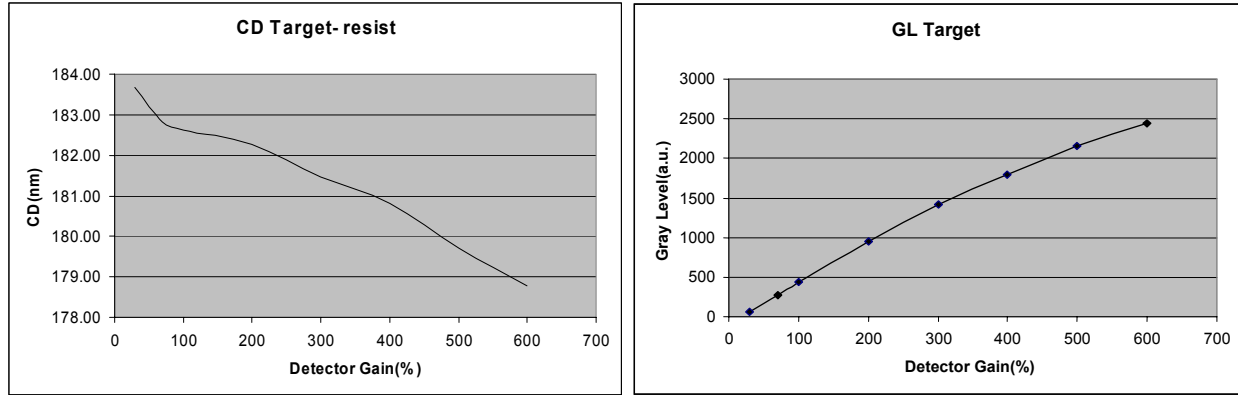


Figure 4a) - b). Verification of the Gray Level Target in experiment on CD SEM Tool for Etch layer: a) Results of CD measurements (CH bottom diameter) on the images from Figure 3; b) Results of Gray Level Target measurements of the same images.

Let's consider the region of detector gain changing around nominal value – from 50% to 150%. The observed changing of CD value is around 1 nm with precision 0.3 nm and the changing of Gray Level metrics will be from 500 to 1500 with precision 50 levels. From these data we can conclude that sensitivity and robustness of Gray Level Target much higher in comparison with CD target.

3.1.3 Comparison with Litho layer

In Figure 5a,b we demonstrate that influence of detector gain changing on CD measurements for resist layer is different in comparison with Etch layer (See, for comparison, Figure 4a,b). The CD changing corresponding to 50%-150% range of detector gain is comparable with precision (0.3 nm). We conclude that CD target can not be useful for accurate monitoring of detector gain. We should underline that despite small value of CD changing, we can not neglect this effect for 32-45 nm nodes tight ITRS requirements.



a)

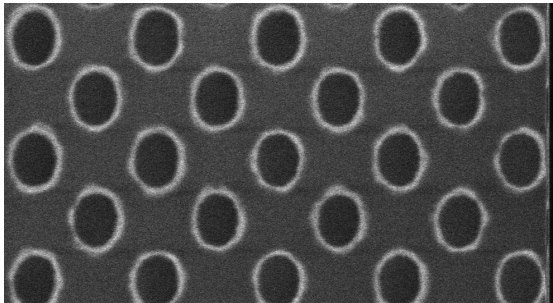
b)

Figure 5a) - b). Verification of the Gray Level Target in experiment on CD SEM Tool for Resist layer: a) Results of CD measurements (CH bottom diameter) on the images from Figure 3; b) Results of Gray Level Target measurements of the same images.

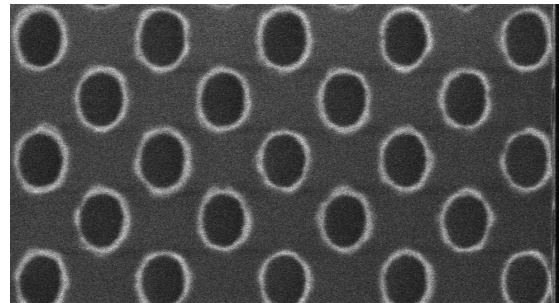
3.2 Noise Monitoring Target feasibility study

3.2.1 Simulation study

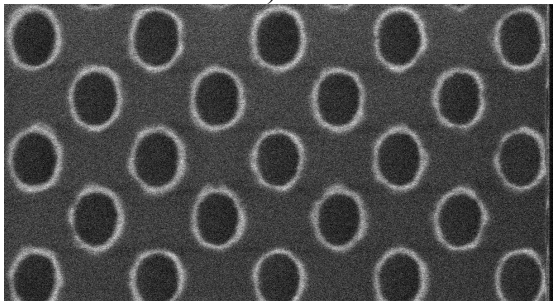
At first, we present the CD measurements of images that are synthetically added with white Gaussian noise with different variance values. Our purpose is to estimate the influence of the image noise variance related to the images acquisition noise on CD measurements. It was found that due to high robustness of CD Measurements algorithm for specific layers, a strong changing of noise variance that can affect tool matching on other layers can not be detected by CD measurements. We use image with 2^{16} gray level dynamic range.



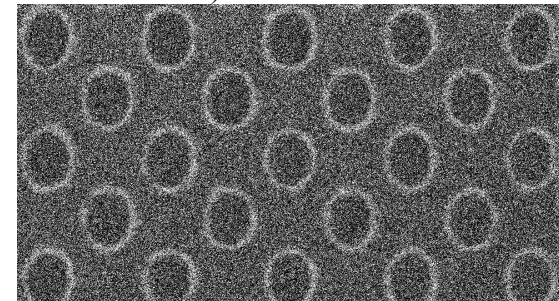
a)



b)



c)



d)

Figures 6a)-6d). CD Noise Target with different noise variances (Simulation in Matlab): a) original image, b)-d) image added with white Gaussian noise b)(AWGN) $\sim N(0, 2^5 \text{ gray scale})$, c) AWGN $\sim N(0, 2^{10})$, d) AWGN $\sim N(0, 2^{14})$.

In Figure 6 few examples of Noise Target images with white Gaussian noise with different variance values that are equal to $0, 2^5, 2^{10}, 2^{14}$ are presented. These images correspond to X-values of 5, 10 and 14 in Figures 7a) and 7b) and to X-values of 0, 6, 32, 128 in Figure 7c).

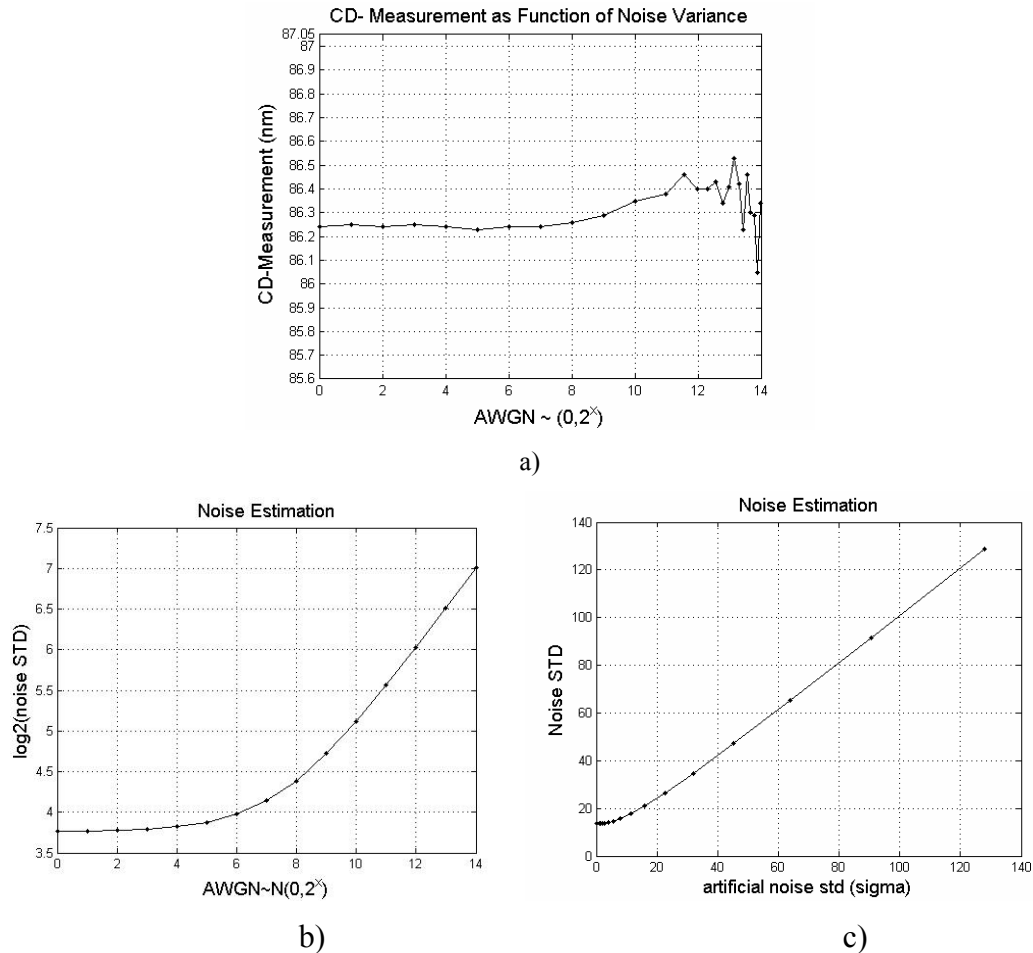


Figure 7a-c). Verification of the Noise Target in simulation experiment: a) Results of CD measurements on the images with increasing noise variance (CH bottom diameter), b) Results of Noise estimation of the same images, c) Results of Noise estimation of the same images, x-axis is the noise variance to demonstrate the proximity of the noise estimation to the artificial noise variance added.

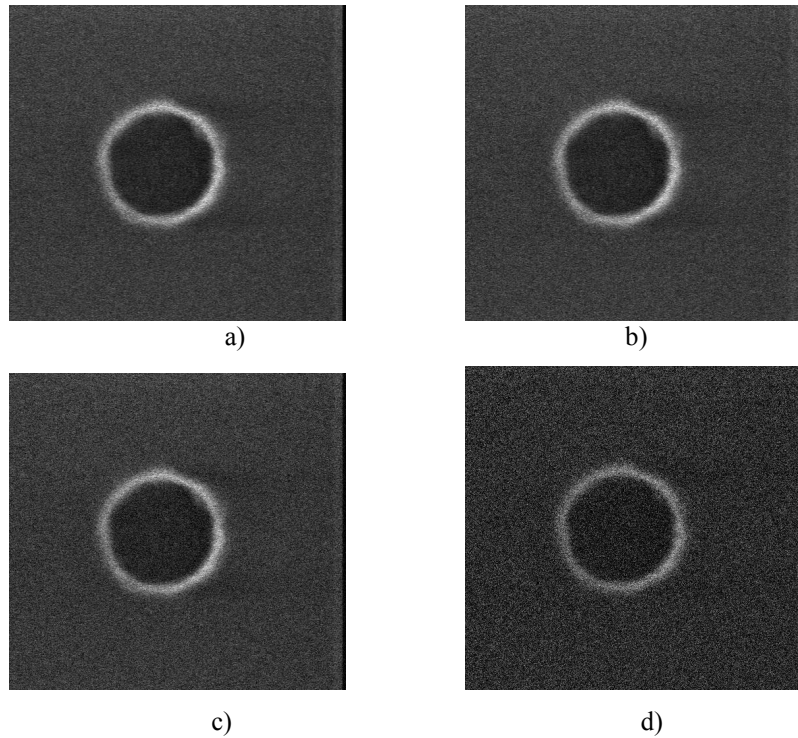
In Figure 7 the results of simulation of noise level influence on CD target and Noise Monitoring Target are presented. It can be observed that there is a relatively small CD changing ($<0.5 \text{ nm}$) for a considerable noise variance change in an image (additive white Gaussian noise with variance in the range $0-2^{13}$ that is reflected with a change of up to 90 gray scales in noise *STD*). It should be underlined that despite the small values of these changes we can not neglect these effects for 32-45nm node spec requirements.

In this example we see that the image has an initial noise variance of $\sim 2^4$ gray scales. When the additive white Gaussian noise variance increases significantly above 2^4 (where the noise variance is for example 2^{10}), the additive noise to the original noise can be detected, while the CD is still in the precision range.

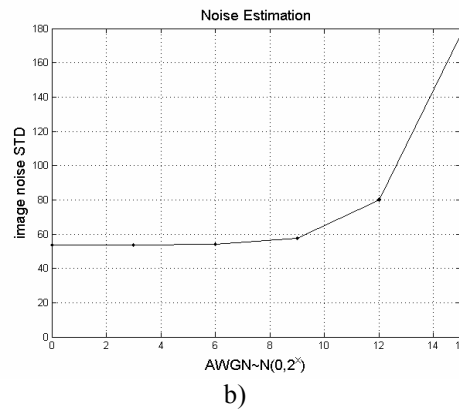
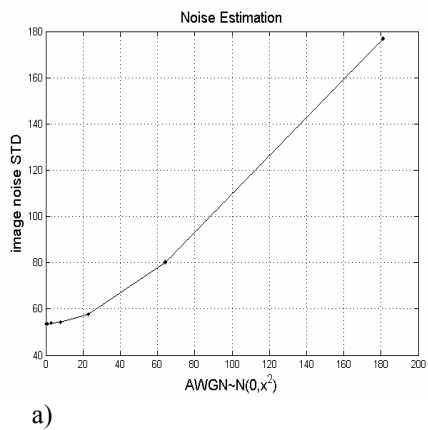
In Figure 8 we present an image of resist layer via features with added noise with different variance values of $2^3, 2^9, 2^{12}, 2^{15}$ gray scales. In Figure 9a-e) the Noise Monitoring Target estimated noise, signal, SNR and CD measurements are presented. The images from Figures 8a)-8d) correspond to the points in Figures 9b)-9e) with X-values 3, 9, 12 and 15 and to the points in Figure 9a) with X-values of 3, 22, 64, 181.

Figure 9a) demonstrates the proximity of the noise estimation to the artificial noise added. In images that were added with high variance noise, the original image noise can be neglected – in that case the noise estimation is equal to the additive noise variance ($x=180$). When the additive noise variance is lower than the original image noise variance ($x<60$), the estimated noise, is influenced from the noise variance of the source image – this why the graph is constant

for $x < 20$ and not equal to 0. Figures 9b)-9d) present the estimated noise, signal and SNR values correspondingly. It can be seen that the estimated signal value (average gray scale) is constant as expected with the different images noise conditions and the SNR decreases as function of the noise variance. Figure 9e) represents the CD measurement precision of the images with different noise values. Each point in this graph is the calculated $3 \times \text{Sigma}$ of the CD measurement of 5 images with the same noise variance (but with different random Gaussian noise). It can be seen that if CD measurements are monitored, only the images with noise variance 2^{15} will be considered flyers and will alert a tool problem, while monitoring the noise *STD* of this target can yield a much early alert of noise drift when the noise *STD* reaches 80 gray scales (for point X=10 in the 9b)-9e)). That is, when the noise variance is 32 times lower than the noise variance that caused the CD measurement to get out of precision.



Figures 8a)-8d). CD Noise Target with different noise variances (Simulated in Matlab) a) original image; b)-d) image added with white Gaussian noise: b) AWGN $\sim N(0, 2^3)$ gray scale; c) AWGN $\sim N(0, 2^9)$; d) AWGN $\sim N(0, 2^{15})$.



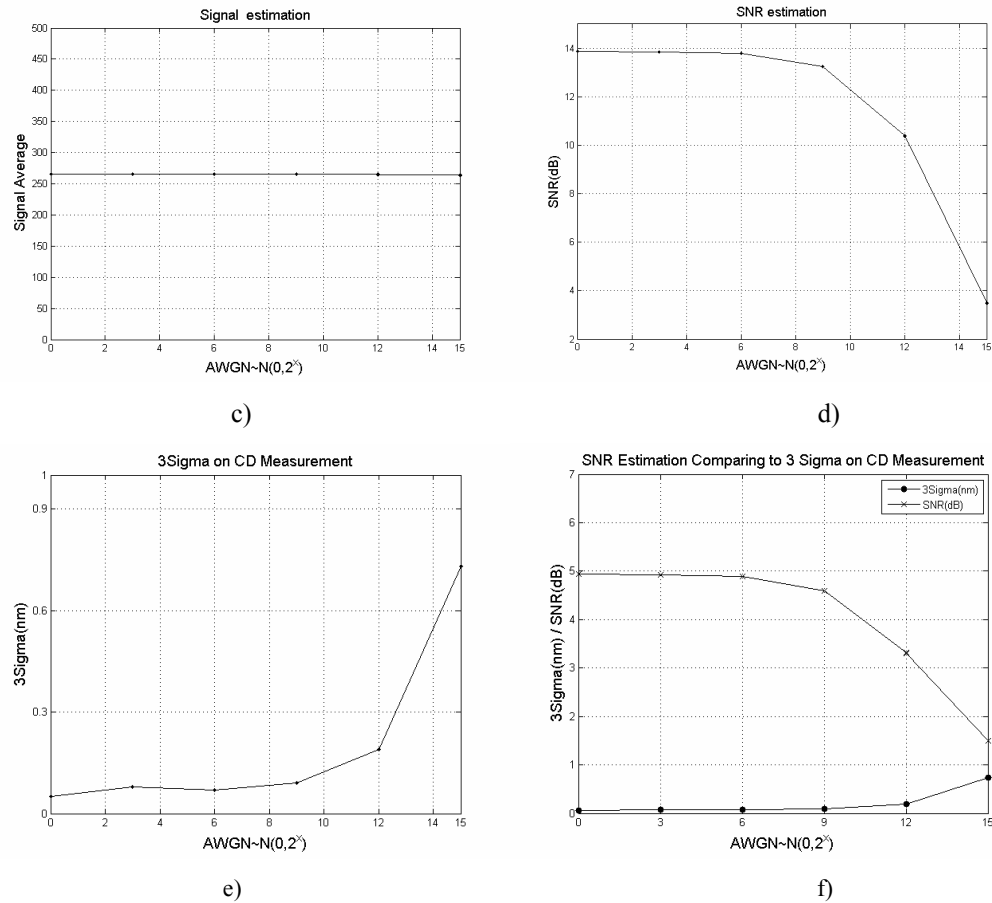


Figure 9a)-e). Estimation of noise variance, signal average value, SNR STD and CD precision of same source image with different noise; a) Noise STD of the simulated noise on resist image; b) Noise STD of the simulated noise on resist image (logarithmic x-axis); c) Signal average gray scale estimation; d) Estimated SNR in dB; e) 3Sigma of the CD measurements of the feature as a function of noise variance; f) comparison between the SNR changes and the 3 sigma changes as function of noise.

3.3 Relation with CD based Tool Management metrics - FMT and TMP

The great advantage of the fleet management metrics FMP and TMP that were introduced in [1, 3] is the CD units of measurement— length units (*nm*). This allows to relate these metrics to ITRS requirements for specific technological nodes and layers. For practical use of Physical targets we should find the way to translate the “Physical Matching” targets outputs into standard CD units. The natural question of the process engineer will be about acceptable levels of discrepancies of the correspondent physical parameters through tool fleet. This translation is possible through simulation of the influence of physical parameters measurement into CD units with help of tool calibration procedure. For example, using plots in Figures 4 and 5, we can predict the changing of CD corresponding to the observed changing of gray level through tools set for resist and etch layers correspondingly. The same procedure can be applied to Noise Monitoring Target and other Physical Targets that will be introduced in the future. Detailed investigation of this problem will be performed in the future.

4. CONCLUSIONS

We demonstrated that CD targets can provide a limited CD SEM tool fleet matching. We propose to introduce in addition to traditional FMP and TMP fleet matching metrics the new “Physical Matching” metrics based on the direct measurements of CD SEM physical parameters. The concept is verified for Gray Level and Noise Monitoring targets. Simulation and the test experiments for different layers were performed on CD SEM tool. The using of new targets can

provide more accurate tool state monitoring, Tool to Tool and Vendor to Vendor matching for all production layers and accelerate Root Cause Analysis for fleet matching management.

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