# Measurement results on after etch resist coated features on the new Leica Microsystems' LWM270 DUV critical dimension metrology system

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## Abstract

Process control in photomask manufacturing is crucial for improving and maintaining optimal yields. The LWM270DUV critical dimension (CD) measurement system is the first tool ever designed for photomask manufacturers that combines both UV (365 nm wavelength light) and DUV (248 nm wavelength light) for CD measurements. UV light illumination was integrated into the LWM270 DUV to allow photomask makers to perform after etch inspection (AEI) on DUV resists minimizing exposure effects. The increased resolution of UV illumination allows for measurement of features as small as 300 nm. Improved measurement algorithms as well as improvements in the illumination system have reduced the uncertainty of measurements resulting in improved performance. This paper details recent measurement results of various feature types on different substrate types using UV transmitted light.

## I. Introduction

The various models of LWM CD systems and the optics from Leica Microsystems have been described in detail in a number of prior papers [1,2,3,4,5,6]. This paper in particular shows recent results on a variety of features that have been etched, but not stripped of resist. Measuring these features using DUV illumination results in resist degradation and exposure as a result of the resist sensitivity to the DUV (248 nm) wavelength. By using UV (365 nm) illumination combined with a gray filter and an illumination shutter it is possible to reduce radiation intensity such that after etch resist features can be measured with minimal degradation or exposure effects. This measurement capability allows for greater latitude in the development process for CD size control for final feature sizes. Combining both UV and DUV illumination into a single tool helps reduce equipment costs for photomask manufacturers.

The measurement system was equipped with a 150x, 0.95 NA UV objective lens. The effective pixel size of the CCD array of the video camera was 16 nm in the X and Y directions. System calibration (pixel calibration) was done using a single point pitch measurement. The photoresist on the photomasks was only subjected to UV illumination/exposure during site alignments and measurements. Three photomask were measured with various features types on each substrate. All measurements were done using a "through focus" algorithm whereby the various intensity profiles at different focus values are stored and analyzed for optimum edge sharpness.

If the resist is exposed to too much UV or DUV illumination (radiation) it will degrade the measurements through exposure. This results in an apparent drift in the measurement results resulting in increased 3 sigma measurement values.

## II. Measurement results on Plate 1

Plate one is a binary COG coated with I-line (365 nanometer) resist and contains two pattern types that were measured. Pattern A consists of lines and spaces ranging in size from 0.25 microns to 1 micron, and contact holes also ranging in size from 0.25 to 1 micron. The pattern A lines and spaces as well as contacts were measured 15 times. These 15 feature measurements were completed in 15 "measurement loops." A measurement loop consists of aligning on the measurement site, performing one measurement, moving to the next site and repeating the process. This is how the 3 sigma measurement precision values on the figures was derived. Figure 1 shows the 3 sigma measurement precision values of the Pattern A lines and spaces.

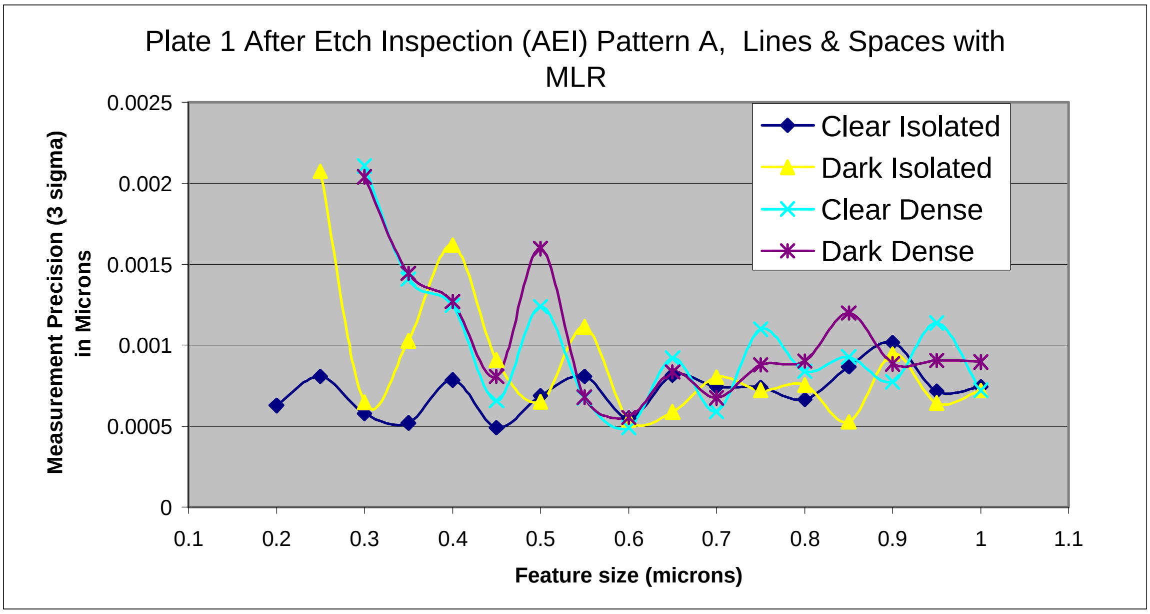


Figure 1

All measurements were done using the new Leica Microsystems illumination homogenization micro lens array (German: Mikro Linsen Raster = MLR) to minimize the effect of lamp fluctuations, and to minimize coherency effects. Figure 2 shows the patter "B" proximity line.

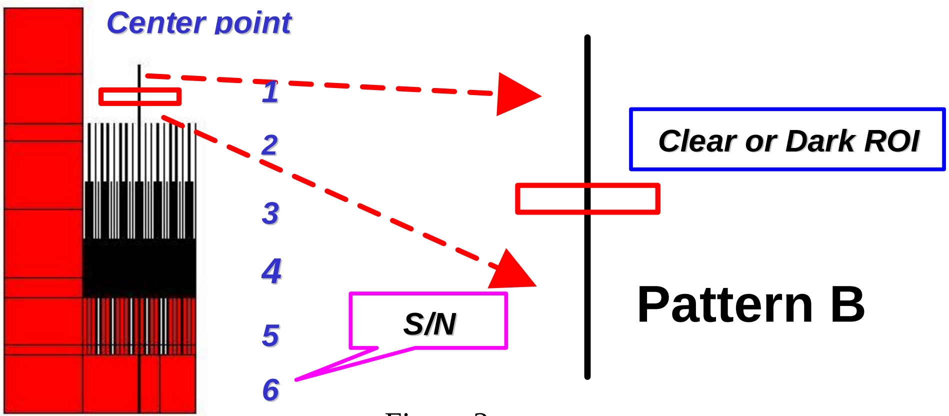


Figure 2

Figure 3 shows the 3 sigma measurement results on clear contacts.

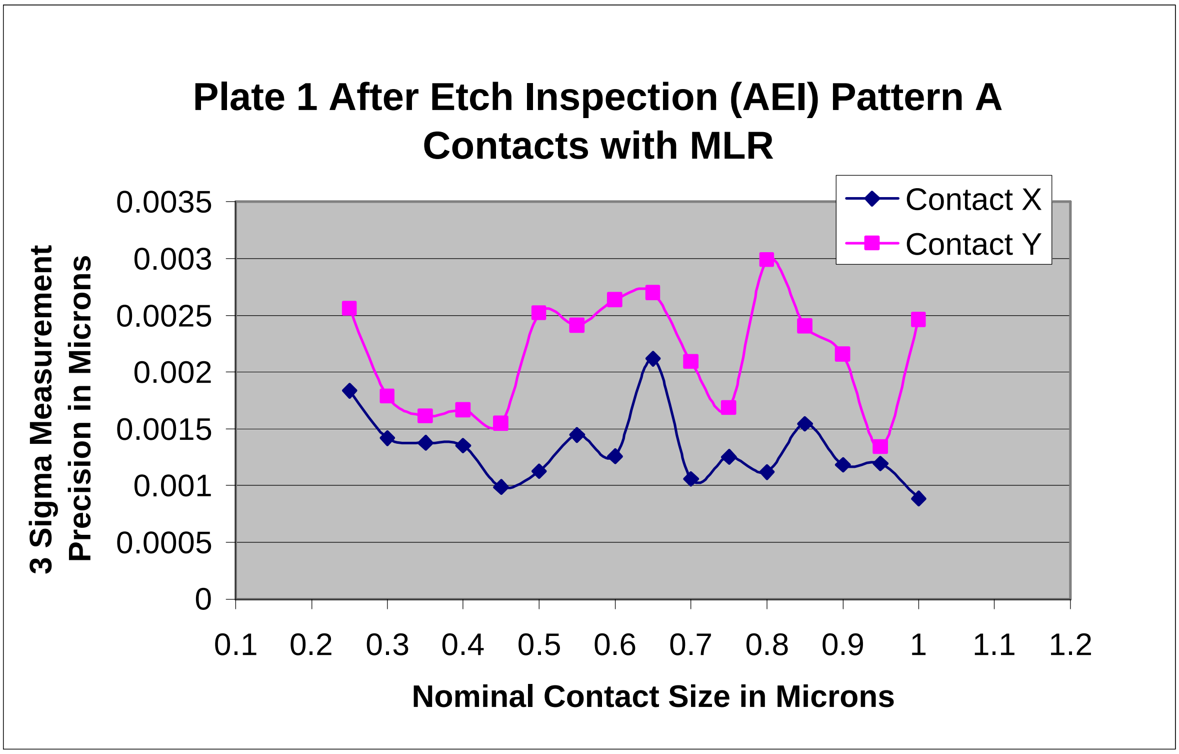


Figure 3

Table 1 shows the 3 sigma measurement precision results of Pattern B in microns. Pattern B on plate 1 is a proximity pattern. The Pattern varies from a fully isolated clear line above fully dense lines and spaces to a fully isolated opaque line. (SN1 to SN6). Please see Figure 4.

These 6 proximity pattern lines were measured in 30 "measurement loops."

| | SN 1 | SN 2 | SN 3 | SN 4 | SN 5 | SN 6 |
|---|---|---|---|---|---|---|
| mean | 0,67045 | 0,67562333 | 0,67829333 | 0,69484 | 0,70313333 | 0,69837667 |
| 3 sigma | 0,00031266 | 0,00042194 | 0,00050405 | 0,00059793 | 0,00038863 | 0,00059315 |

Table 1

### III. Measurement Results on Plate 2

Plate 2 is a Krf (248 nm) Phase Shift Mask (PSM). On this phase shift mask only the clear contacts were measured. Measurements were conducted in a similar manner as on Plate 1. Fifteen "measurement loops" were completed to derive the precision values as shown in Figure 3. As can be seen from figure 3 the measurement precision uncertainty on the contacts was less than 2.5 nanometers.

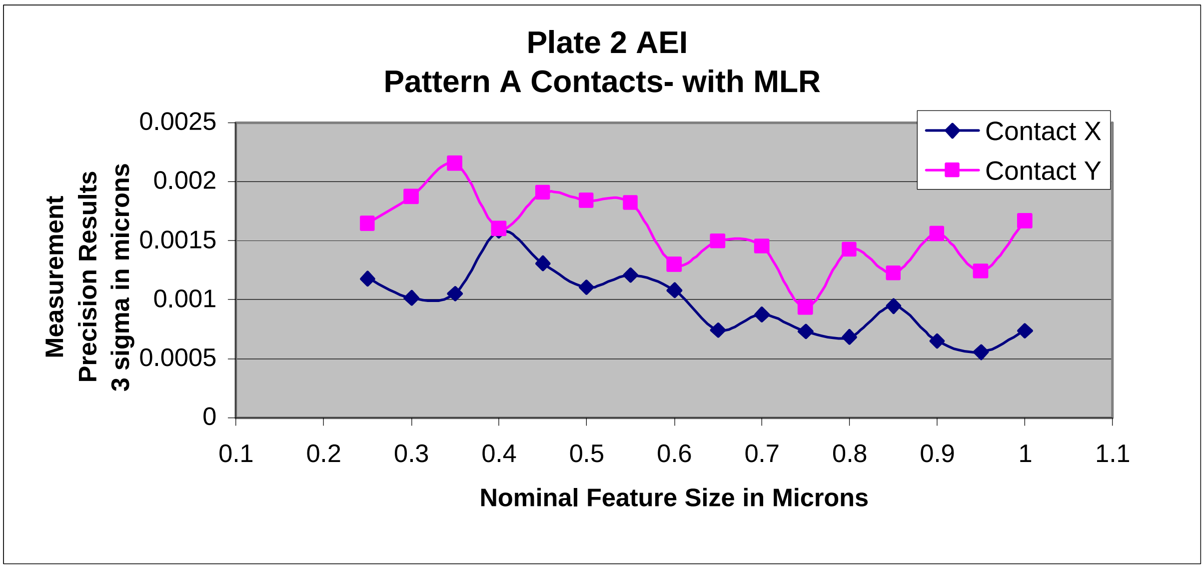


Figure 4

### IV. Measurement Results on Plate 3

Plate 3 is an ARF (193 nm) PSM. AEI measurements were done in a similar manner as on plates one and two. Fifteen "measurement loops" were performed to derive the 3 sigma precision results. Figure 5 shows the results of Pattern "A" measurements on clear and dark tone isolated and dense lines. The maximum uncertainty of these resist covered features was less than 2 nanometers, 3 sigma.

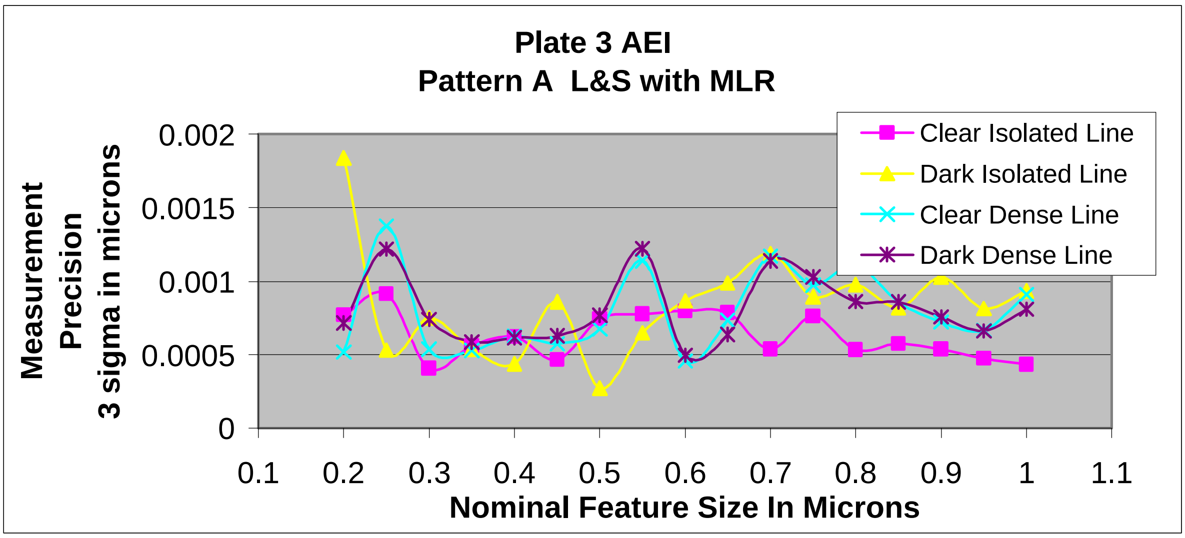


Figure 5

Figure 6 shows the measurement results of clear contacts on plate 3. Again, the 3 sigma measurement results were derived from fifteen "measurement loops." The 0.25 micron contact did not resolve.

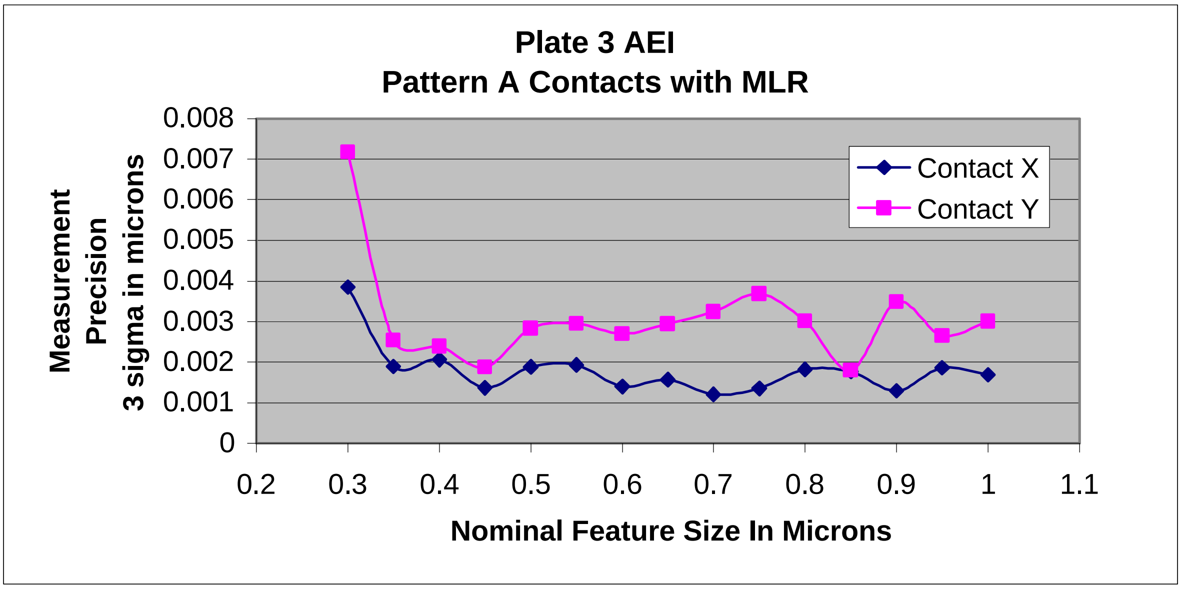


Figure 6

Plate 3 also contains pattern features similar to Plate 1. Table 2 shows the 3 sigma measurement results on a proximity pattern with a nominal value of 0.3 microns. Only "X" lines are on the plate. The Pattern varies from a fully isolated clear line above fully dense L&S to a fully isolated opaque line. (SN1 to SN6) as describe for plate 1.

The maximum 3 sigma value on the 0.3 nominal lines is 2.6 nm.

| Plate 7 | SN 1 | SN 2 | SN 3 | SN 4 | SN 5 | SN 6 |
|---|---|---|---|---|---|---|
| mean | 0,28668667 | 0,28991333 | 0,28882667 | 0,28796667 | 0,30384 | 0,30434667 |
| 3 sigma | 0,00123624 | 0,0010322 | 0,00238783 | 0,00257488 | 0,00103799 | 0,00236999 |

Table 2 repeatability of Pattern B measurements in micron

Tables 3 and 5 show the mean values of measured clear contacts in a dense contact hole array. Tables 4 and 6 show the 3 sigma measurement results of fifteen measurement loops. Tables 3 and 4 show the "X" values and tables 5 and 6 show the "Y" values. The maximum 3 sigma measurement precision uncertainty on the Arf (193 nm) PSM for "X" is 3.6 nanometers and for "Y" the maximum value is 6.3 nm. The average 3 sigma values are smaller. Table 7 shows the "X" direction average value is 2 nanometers and the average "Y" axis value is 4 nanometers.

| | | | | | |
|---|---|---|---|---|---|
| 0,479622 | 0,473381 | 0,48542 | 0,46793 | 0,48196 | 0,46626 |
| 0,47478 | 0,45487 | 0,46263 | 0,44648 | 0,46448 | 0,44484 |
| 0,50209 | 0,47371 | 0,47316 | 0,46712 | 0,48556 | 0,46944 |
| 0,47538 | 0,45336 | 0,46589 | 0,44994 | 0,46559 | 0,44793 |
| 0,47277 | 0,46854 | 0,47858 | 0,46706 | 0,48275 | 0,46508 |
| 0,46971 | 0,46106 | 0,46898 | 0,45142 | 0,46535 | 0,44644 |

Table 3 Mean values of contact hole array in X direction in microns

| | | | | | |
|---|---|---|---|---|---|
| 0,00196 | 0,00189 | 0,00244 | 0,003385 | 0,00191 | 0,002913 |
| 0,00154 | 0,00149 | 0,001049 | 0,002407 | 0,00237 | 0,00195 |
| 0,003587 | 0,002532 | 0,00155 | 0,001771 | 0,00169 | 0,002246 |
| 0,002139 | 0,003614 | 0,001723 | 0,002483 | 0,00149 | 0,001192 |
| 0,001443 | 0,001226 | 0,002249 | 0,001971 | 0,00208 | 0,002297 |
| 0,001723 | 0,000908 | 0,001826 | 0,001384 | 0,00187 | 0,001282 |

Table 4 3 sigma values of contact hole array in X direction in microns

| | | | | | |
|---|---|---|---|---|---|
| 0,465178 | 0,457611 | 0,46521 | 0,44799 | 0,46013 | 0,44364 |
| 0,45482 | 0,44361 | 0,44905 | 0,43186 | 0,44571 | 0,42854 |
| 0,47724 | 0,45718 | 0,45904 | 0,44781 | 0,46241 | 0,44692 |
| 0,45455 | 0,43527 | 0,45074 | 0,43349 | 0,44709 | 0,4315 |
| 0,46053 | 0,45764 | 0,45957 | 0,45206 | 0,46281 | 0,45031 |
| 0,45627 | 0,449 | 0,45248 | 0,43621 | 0,44779 | 0,43196 |

Table 5 Mean values of contact hole array in Y direction in microns

| | | | | | |
|---|---|---|---|---|---|
| 0,004681 | 0,004692 | 0,004342 | 0,005496 | 0,00438 | 0,00255 |
| 0,004108 | 0,005498 | 0,002761 | 0,003832 | 0,00262 | 0,002401 |
| 0,004155 | 0,004551 | 0,003516 | 0,003675 | 0,00397 | 0,002513 |
| 0,003915 | 0,003286 | 0,004038 | 0,003767 | 0,00418 | 0,004481 |
| 0,003776 | 0,002228 | 0,005337 | 0,004355 | 0,00482 | 0,004444 |
| 0,00445 | 0,003338 | 0,006272 | 0,003738 | 0,00303 | 0,003412 |

Table 6 3 sigma values of contact hole array in Y direction in microns

| Contacts | Average 3s |
|---|---|
| 3 sigma X | 0,0019885 |
| 3 sigma Y | 0,003961 |

Table 7 Overall Average performance on Contact hole array in microns

## V. Conclusion

The measurement precision on lines and spaces is superior to contacts. Minimizing the resist exposure to UV radiation, despite repeated measurements, allows for stable high precision measurements on I-line, Krf, and Arf PSMs. Measurement results on contacts was generally very good and an improvement over older LWM versions. Photomask makers have an opportunity utilizing after etch feature measurements to better characterize their development processes. On a long term basis this should lead to improving critical dimension resist variances and a general improvement in final critical dimension variances.

Contact measurement precision has improved dramatically on the LWM 270 UV/DUV system through improved illumination homogeneity and through improved measurement algorithms. As a general rule small contact features generally exhibit corner rounding characteristics making it difficult to obtain good "X/Y" edges. The resolution of the exposure systems and the resist process capability typically have a direct effect on measurement precision of contact sizes below 0.5 microns.

By incorporating UV illumination capability with DUV illumination the versatility of the critical dimension measurement tool can be improved providing greater value for the end users.

## VI. Literature


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