# A Study of Wafer Plane Analysis with Mask MVM-SEM® using 2D and 3D Images

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# 1. Motivation

## Background

- DUV extension through 1Xnm technology node and beyond is a consensus in the industry
- The management of mask defects which are to be transferred onto wafer becomes much more important.
- The photomask pattern becomes smaller and more complicated due to RET technologies such as Inverse Lithography Technology(ILT) and Optical Proximity Correction (OPC) with Source Mask Optimization (SMO).
- Verification of mask defects with optical method is challenged due to its insufficient resolution in such advanced technology environment.

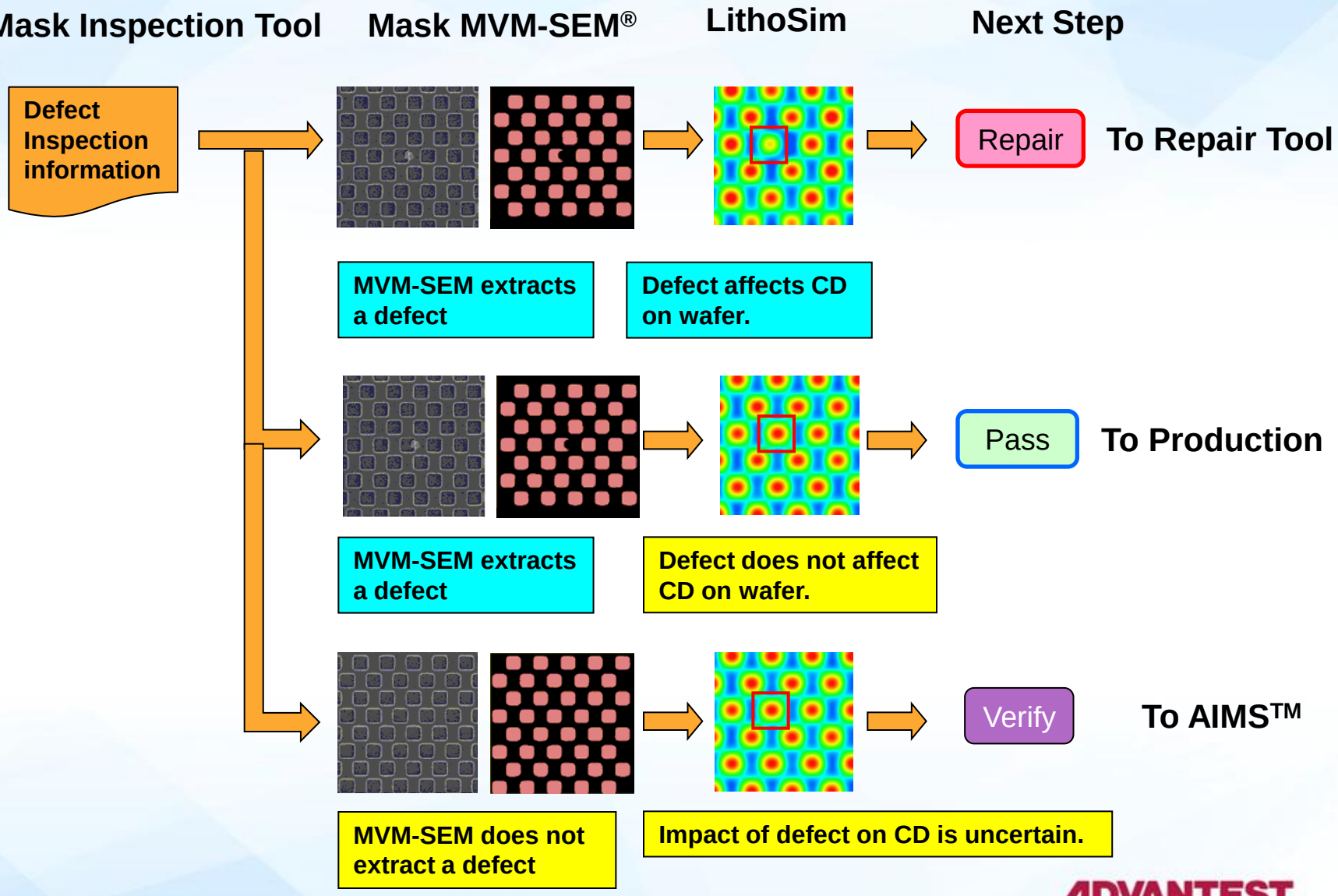
# 1. Motivation
## Background

### In this study

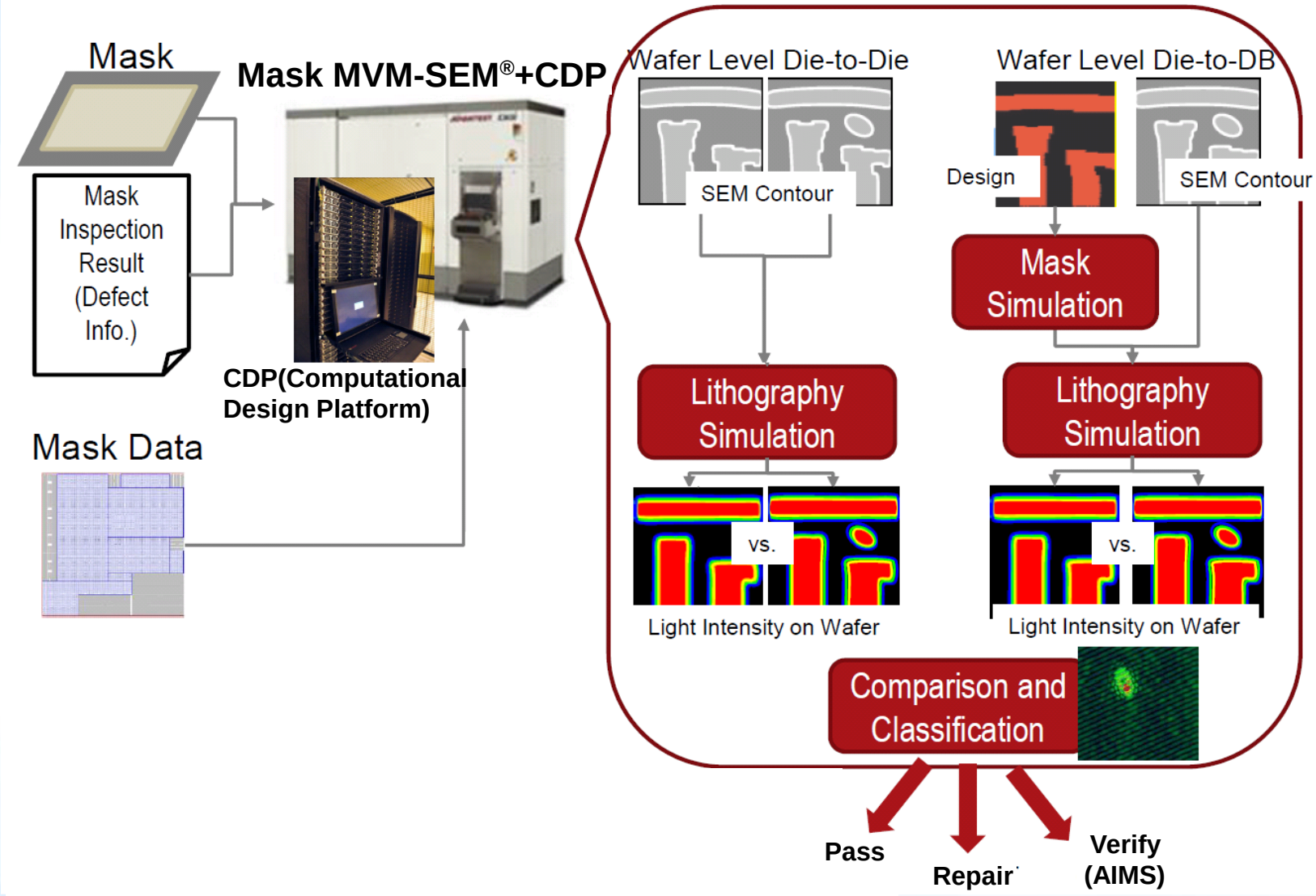
- **We evaluated the correlation between our method using 2 dimensional (2D) images and aerial image microscope.**

- **In order to improve accuracy of defect printability analysis in the future, we applied 3 dimensional (3D) information of CDs and studied if we can improve simulation accuracy for future nodes.**

# 2. Mask Defect Review and Printability Analysis Flow (1)

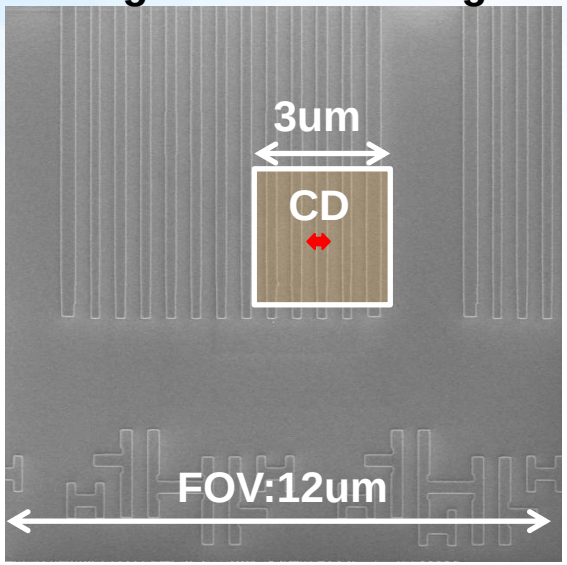


# 2. Mask Defect Review and Printability Analysis Flow (2)

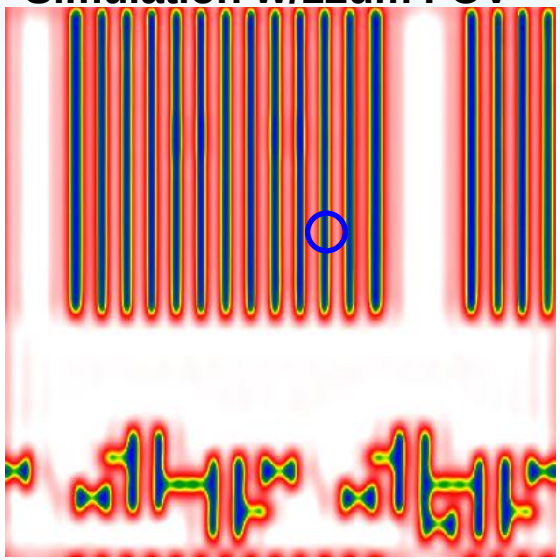


# 3. Influence of FOV size to simulation accuracy

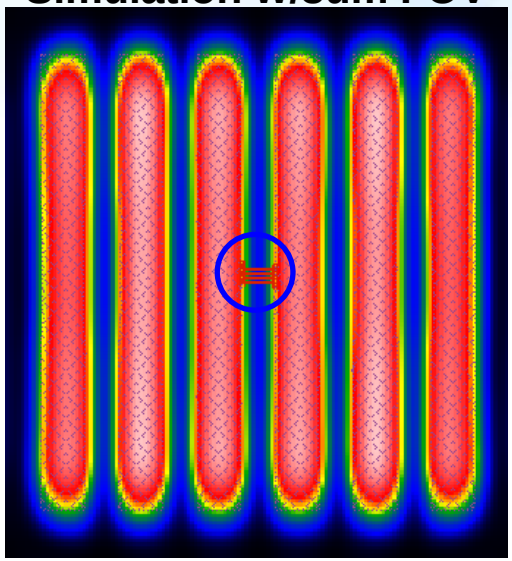
Large field SEM image




Simulation w/12um FOV



Simulation w/3um FOV



CD on wafer: 56.0nm

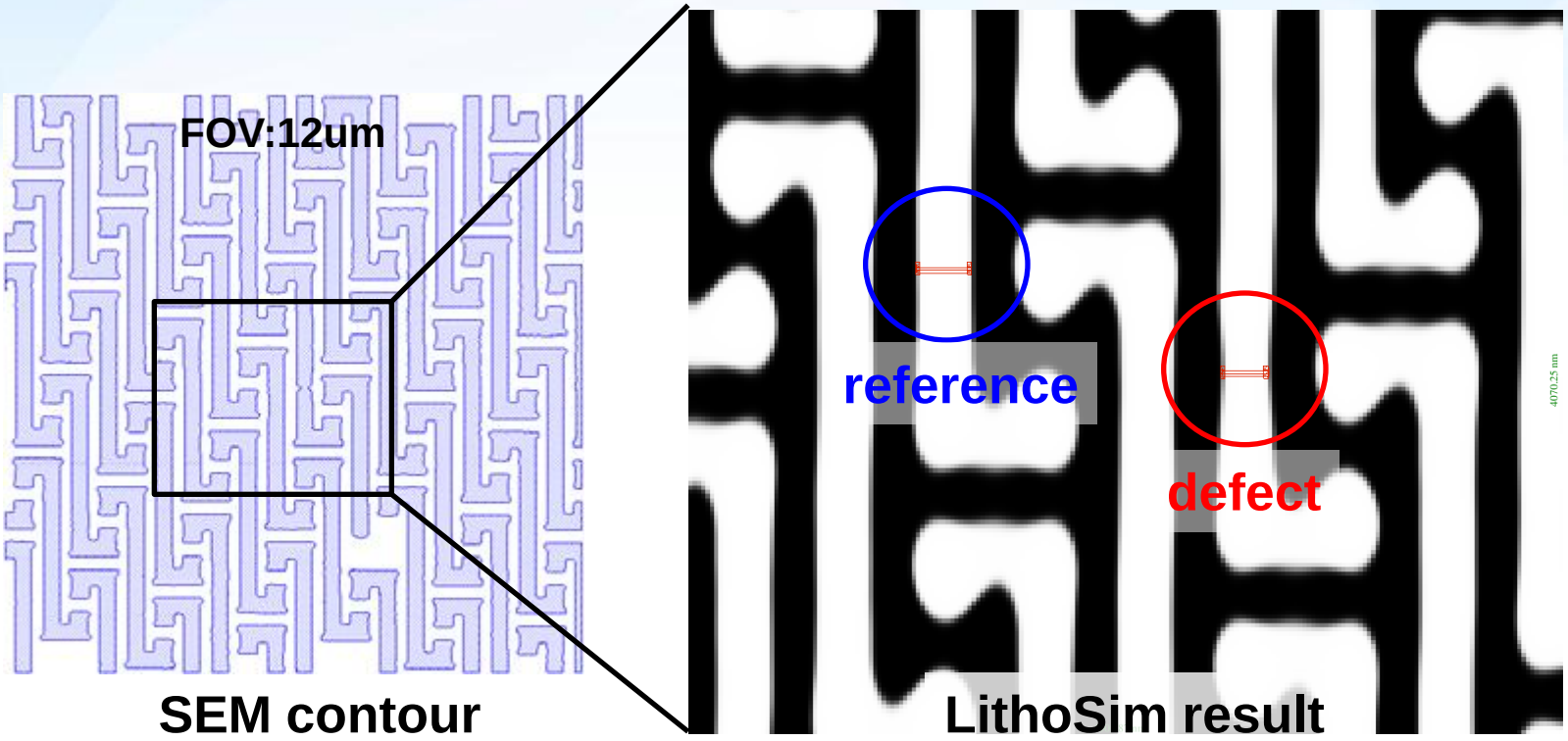
AIMS™ result: 56.0nm (1/4 mask scale)

CD on wafer: 57.9nm

**CD difference is 1.9nm on wafer plane in case of small field.**

**Large field image with Mask MVM-SEM® enables accurate lithography simulation.**

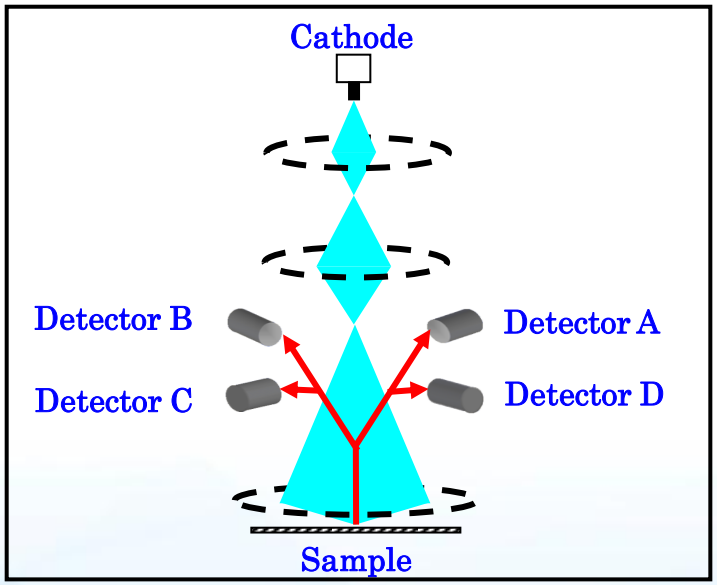
# 4. Large FOV 2D Simulation Correlation



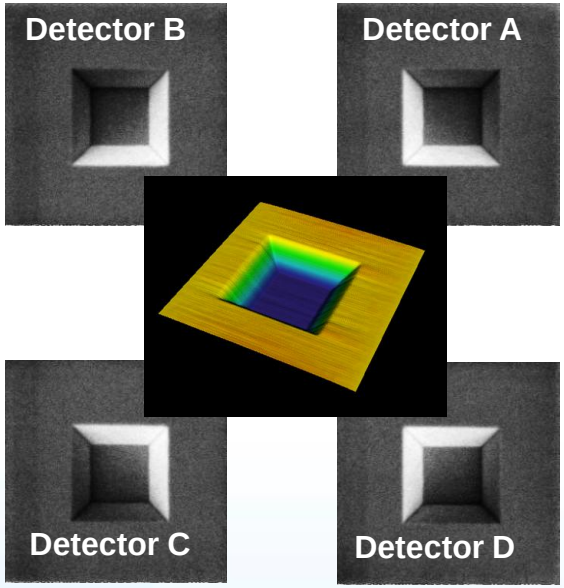

| | Reference(nm) | Defect(nm) | Diff. (%) |
|---|---|---|---|
| MVM SEM+LithoSim | 307.018 | 263.248 | -14.3 |
| AIMS™ | 307.004 | 261.935 | -14.7 |

# 5. Application of MVM-SEM® 3D Capability

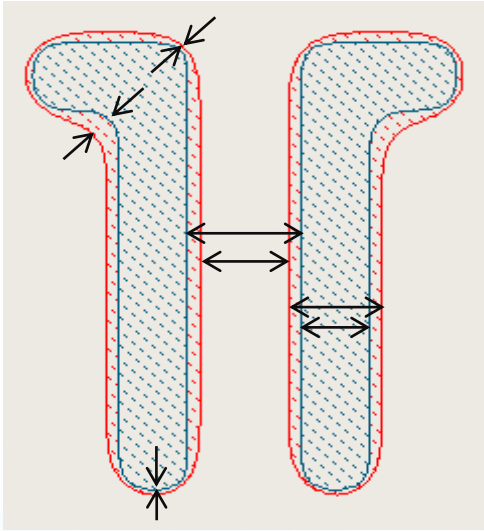
- Mask MVM-SEM® detects top/bottom contour of mask surface as 3D information.
- By using such information, the system can characterize mask processes and verify mask quality more accurately.
- By monitoring mask manufacturing based on the characterization, the system can prevent and/or predict mask process excursion and pattern failure.




MVM-SEM EB column and detectors



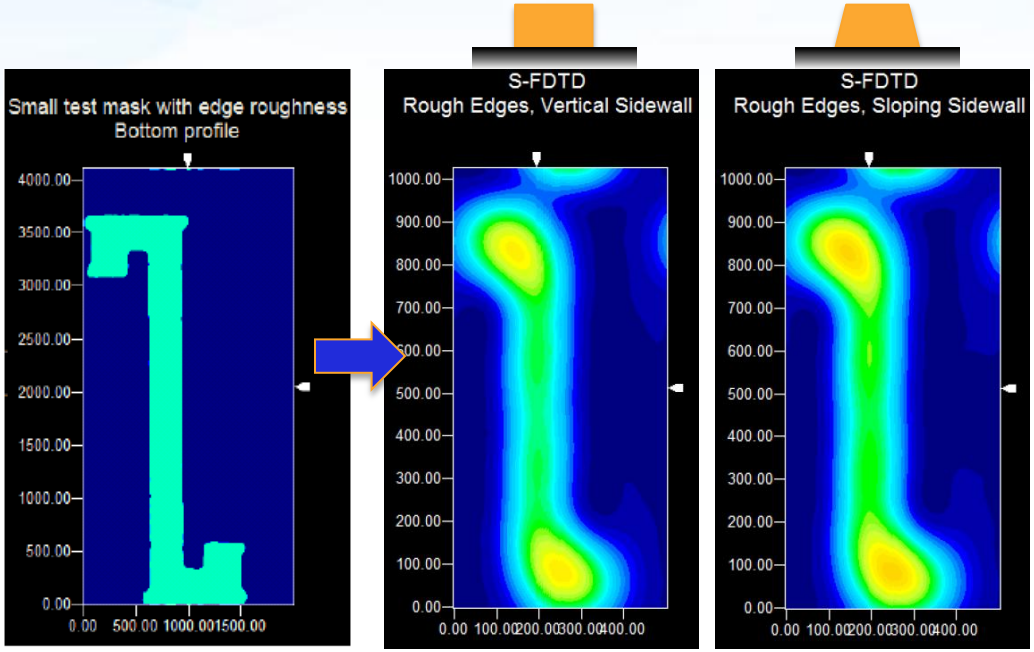

3D images and combined image



Top and bottom contour
(Blue: Top; Red: Bottom)

# 6. 3D Lithography Simulation Study (1)

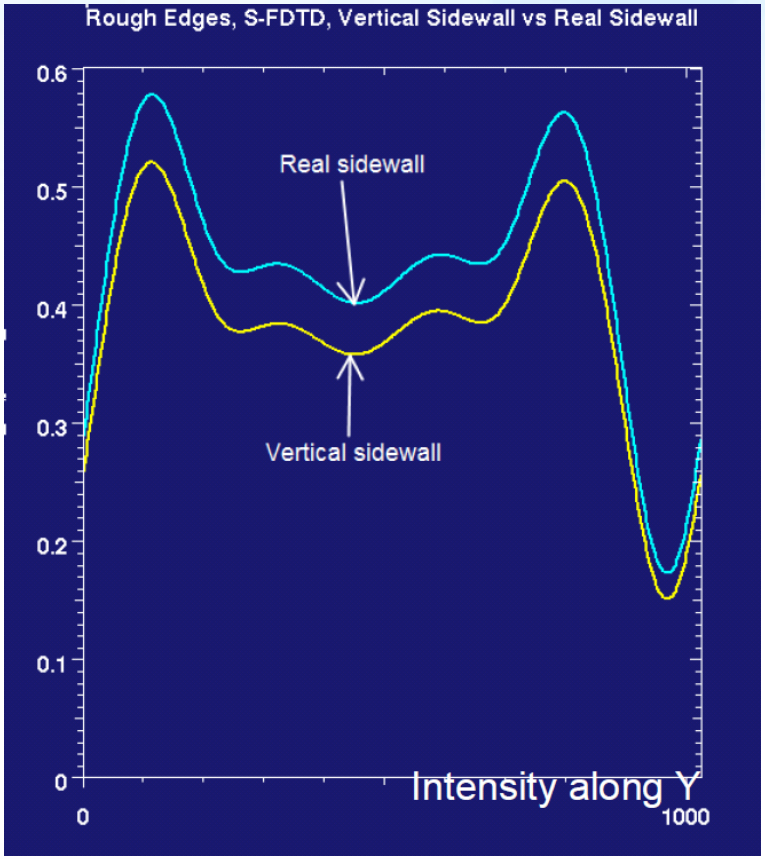
**Effect of sloping sidewall with Fast Rigorous Mask 3D Simulation**




Mask pattern

Vertical sidewall

Sloping sidewall



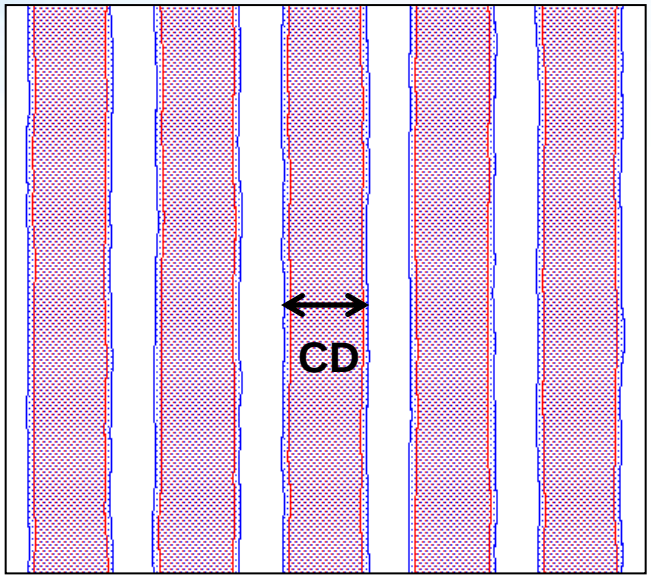

**They show significant difference; Sidewall angle needs to be measured and considered in simulation.**

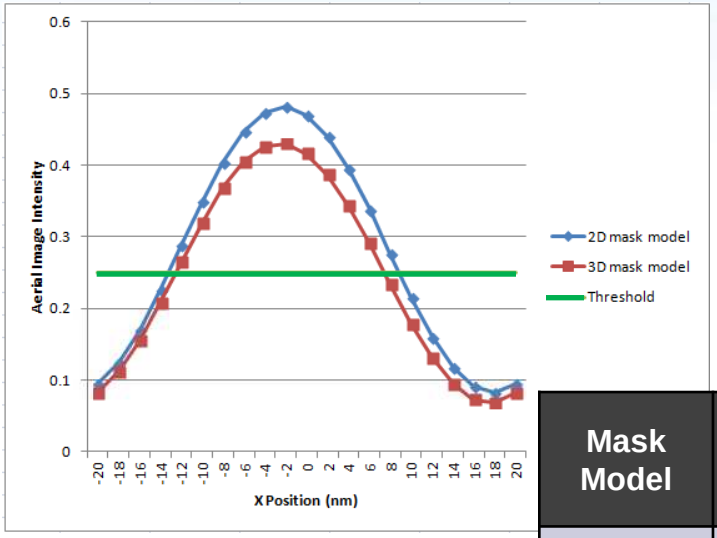
# 6. 3D Lithography Simulation Study (2)

**Extracted 3D SEM mask contour**

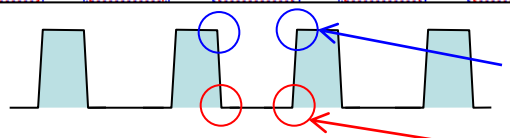
**EUV half pitch 80nm L/S on mask**

**⇒ 20nm expected on wafer.**




| Mask Model | Simulated wafer CD (nm) |
|---|---|
| 2D | 22.1 |
| 3D | 19.9 |



**SEM Contour of Top layer**

**SEM Contour of Bottom layer**

**Extracted mask contour by 3D measurement capability will be useful for more accurate lithography simulation with 3D mask model.**

# 7. Conclusions

- **Large field image captured with Mask MVM-SEM® enables accurate lithography simulation.**
- **Correlation between our simulation methodology and AIMS™ tool using 2D SEM images has been confirmed.**
- **Such methodology can reduce AIMS work load, therefore can reduce turn around time of mask manufacturing.**
- **In addition to 2D cases we studied 3D simulation for masks in advanced technology nodes.**
- **It is found that sidewall slope has a large effect on simulated CDs (>10%). Hence, the real sidewall slope profile must be used.**

# 7. Conclusions

**We believe that this CD verification system with Mask MVM-SEM® and mask/wafer double lithography simulation technology can contribute to improvement of mask processes for advanced technology nodes.**

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AIMS is a trademark of Carl Zeiss.