Using the SHARP EUV Microscope's aerial images to study line edge roughness

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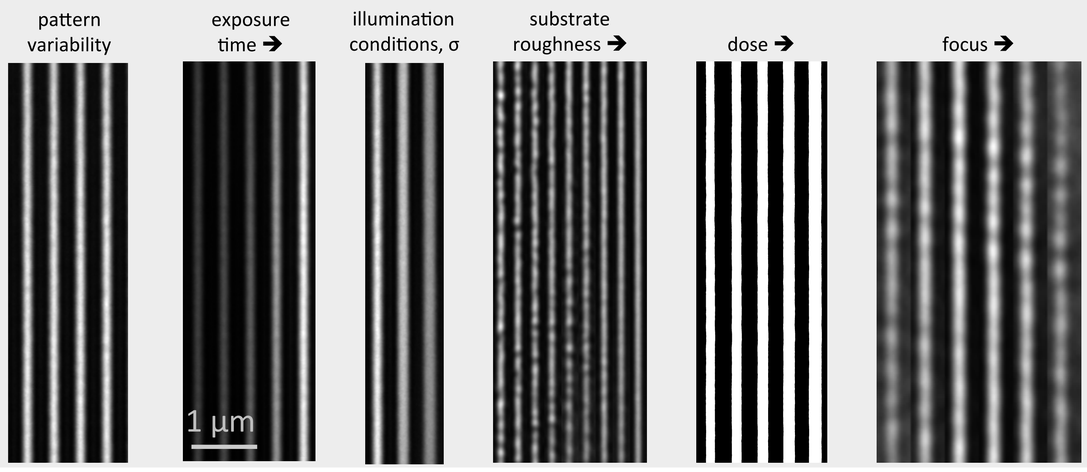
On patterned, reflective EUV masks, substrate roughness imparts phase variations that induce line-edge roughness [1]. Since the local phase and amplitude depends sensitively on the wavelength and illumination conditions, characterization is best performed with a high-resolution actinic (EUV) imaging microscope capable of resolving the aerial image intensity continuously. The SHARP EUV Microscope [2] is designed to emulate current and future lithography printing tools. To better understand and improve imaging results, we are studying the effect of various imaging conditions on real-world aerial images and line-edge roughness in images recorded with SHARP.

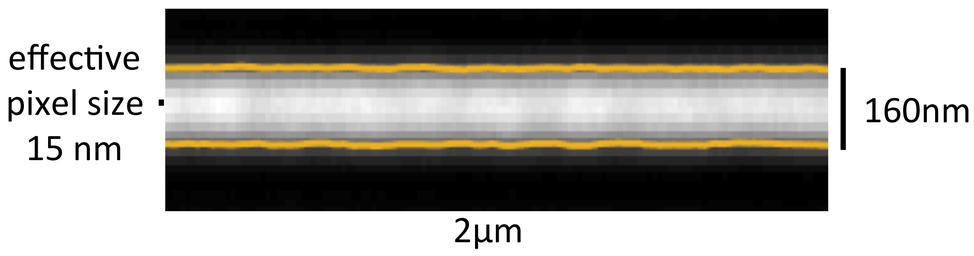
Data

Recorded dense-line images with a wide range of imaging conditions, and with repeated measurements to assess noise.



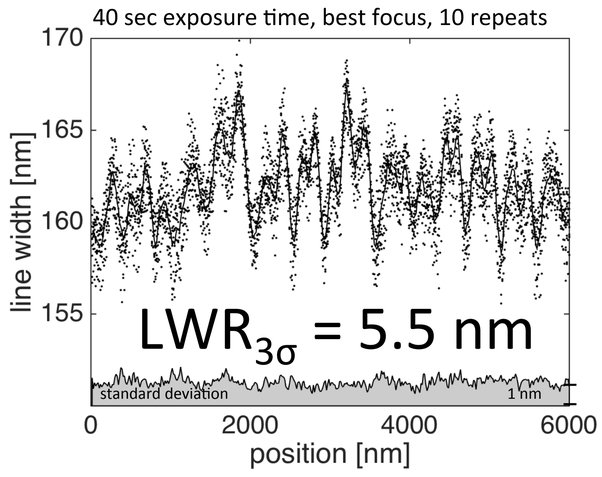
Methodology

Lines extracted from grayscale aerial images with 900x mag on the CCD camera. Background subtraction and normalization are applied. Linear interpolation extracts edge positions with sub-nm precision at the nominal CD values. Repeated measurement isolates the effects of shot noise.



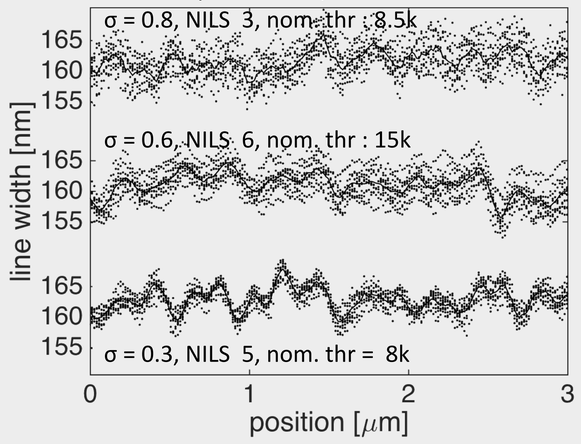
Results

Uncertainty in SHARP edge position measurements comes mainly from photon shot noise. We are investigating the dose required to achieve given precision levels for different edge-slope values.



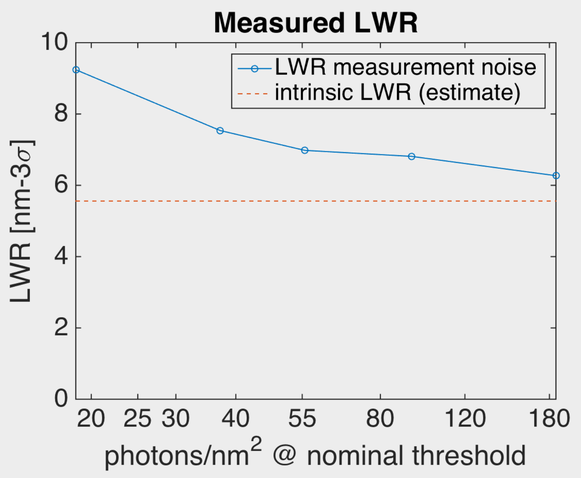
Imaging conditions & LER

The observed LER depends strongly on the line properties (mainly NILS), the illumination coherence, and the exposure level. In this example with large lines, a complex interplay exists.



Influence of noise on measurements

Photon noise induces line-edge position uncertainty [3] that depends on the imaging conditions (*e.g.* lower NILS increases the impact of noise on LER/LWR characterization). Exposure times can be set to achieve a required precision.



Conclusion

As EUV lithography progresses, the impact of mask-induced line-edge roughness becomes increasingly important. [4] Improving the precision of actinic aerial image measurements is critical to defect repair and review efforts. SHARP provides a convenient test-bed for learning about aerial image formation under conventional and exotic illumination conditions coming with source-mask optimization. The study of imaging conditions may uncover ways to mitigate the effects of intrinsic mask roughness on LER/LWR at current and future nodes.

References

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[2] K. A. Goldberg, *et al.*, *Proc. SPIE* **8880,** 88800T, (2013)
[3] D. T. Wintz, *et al.*, *J. Micro/Nanolith. MEMS MOEMS* **9**, 4 (2010)
[4] P-Y Yang *et al.*, Proc SPIE **9422**, 94220J (2015)

Acknowledgements

• LBNL EUV Program supported by:
EUREKA (Intel, Samsung, TSMC)
• Initial MET5 funding by SEMATECH