Inspection Efficiency Comparison between Phase Contrast & Dark Field Microscopy for EUV Actinic Blank Inspection

Yow-Gwo Wang[1.2], Andy Neureuther[1.2], Patrick Naulleau[2.]
1.University of California, Berkeley. 2.Lawrence Berkeley National Laboratory

Motivation

- Compare the inspection efficiency (defect SNR) between Phase contrast (AZPC) and Dark filed (DF) techniques for EUV actinic blank inspection.
- Signal-to-Noise ratio (SNR) =

$$\frac{\text{Defect Signal}}{\text{Speckle Noise} + \text{System Noise}}$$

Photon Shot Noise Camera Noise

From Background From Signal

Parameter & Settings - Defects

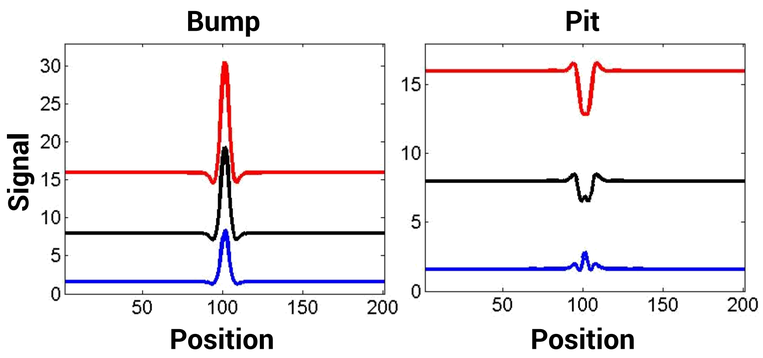
Defect		
Type	Height/Depth	FWHM
Bump/Pit	1 nm	60 nm
Low-Aspect Ratio (LAR) Bump/Pit	1 nm	1000 nm
Carbo Absorber (K = 6.868*10^{-3} at 92 eV)	50 nm	76 nm
Mask Roughness		
RMS	Correlation Length	
60 pm	100 nm	

Parameter & Settings - Optics

Illumination	
NA	0.2
Sigma	0.5
Bright Field Level Photon Density	1 photon/nm^2 (250,000 photons in 500 x 500 nm^2)
Pupil	
Type / Phase Shift / Apodization (Background Transmission)	
AZPC	0 ~ 180° / 100% ~ 10%
DF	0 / 0%

Photon Noise Study: Impact of Defect Type

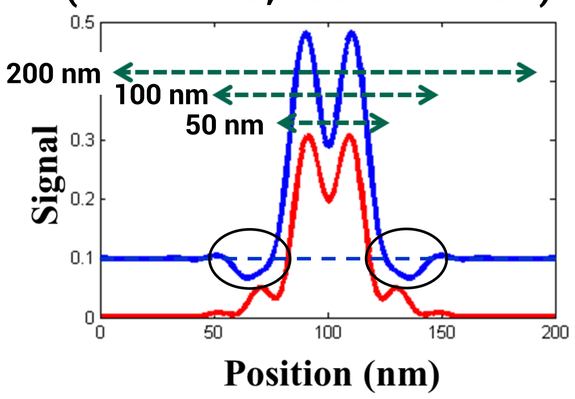
(Blue: 10%, Black: 50%, Red: 100% Background transmission)



- Even though apodization can suppress the background and speckle noise, pit defects which utilize destructive interference will suffer reduced signal.

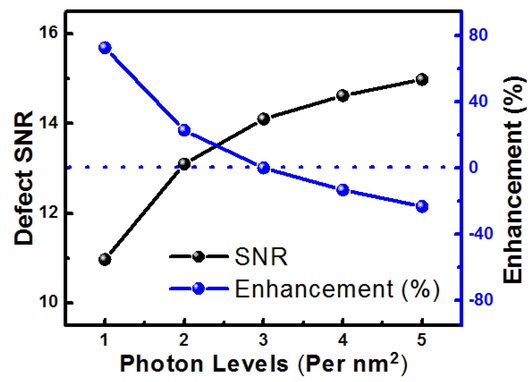
Photon Noise Study: Impact of Resolution

(Blue: AZPC, Red: Dark Field)



- For AZPC, the modulation of signal side lobe can impact the defect signal due to the pixel size (resolution).
- Larger pixel average out the signal enhancement due to the side lobe.

Photon Noise Study: Impact of Photon Level

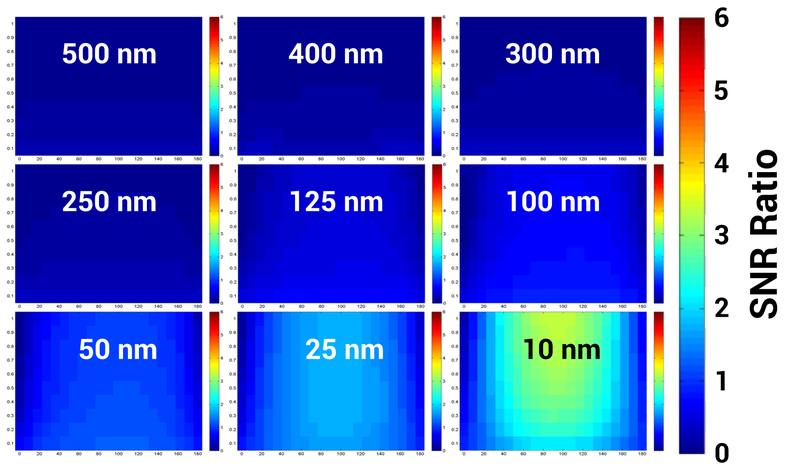


- AZPC shows better performance over DF when it is less than 2 photon per nm^2.

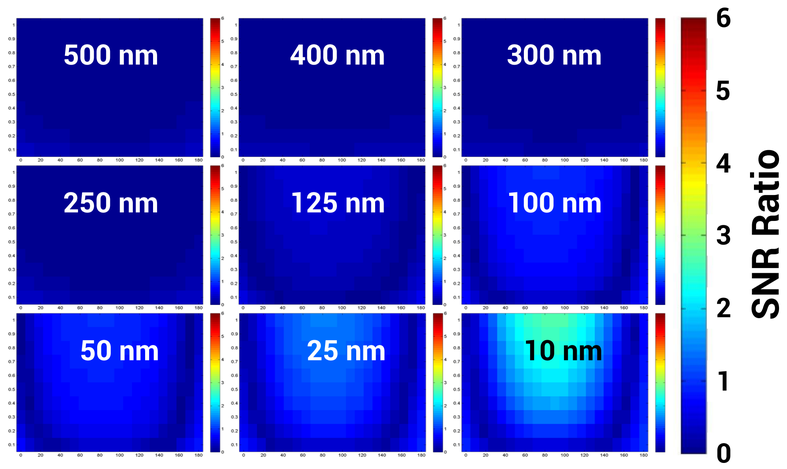
Phase Bump, Pixel Size: 25 x 25 nm^2, Phase Shift: 90°, Apodization: 100%.

Defect SNR Comparison for Various Defects under Different Inspection Conditions

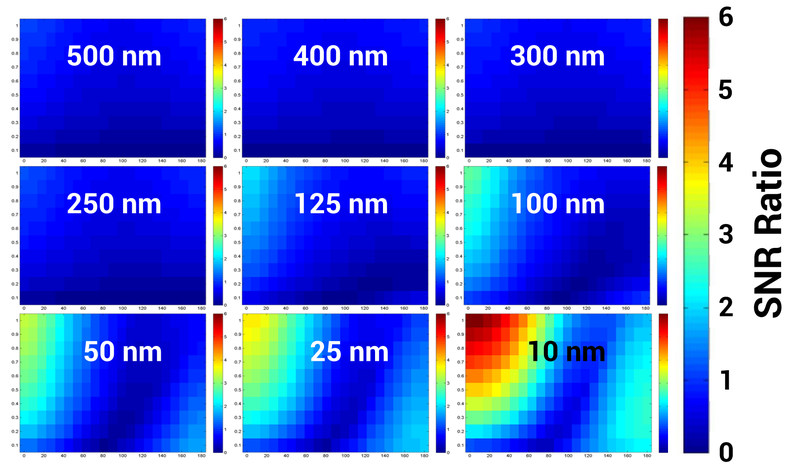
Phase Bump Different Pixel Sizes



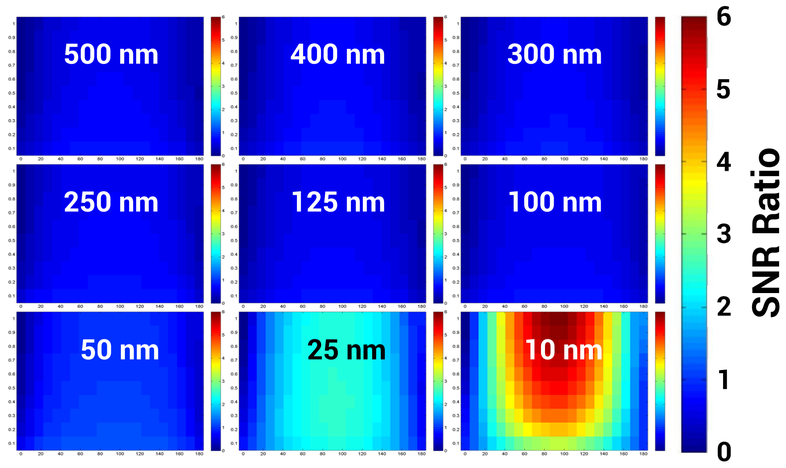
Phase Pit Different Pixel Sizes



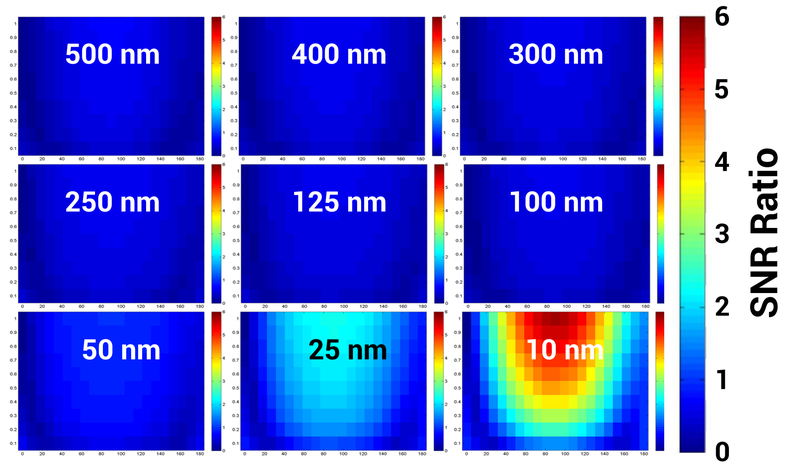
Carbon Absorber Different Pixel Sizes



LAR Phase Bump Different Pixel Sizes



LAR Phase Pit Different Pixel Sizes



- Color Bar Represents the Ratio of Defect SNR from AZPC and DF. (Ex. Ratio > 1 means AZPC is better)
- X-axis: Phase Shift Degree. Y-axis: Apodization (Background Transmission).
- Values in each figure represents pixel size in mask scale.

Conclusion

- AZPC shows better performance over DF when pixel size is less than 25 x 25 nm^2 in mask scale.
- AZPC shows better performance under photon-limited situation (< 2 photons / nm^2).
- Optimum setting should try to maximize the defect signal by phase shifts. Impact of apodization is compensated by the consideration of pit defect and pixel size.

Acknowledgement:
Sponsored by ARM, ASML, Global Foundries, IBM, Intel, KLA-Tencor, Marvell Technology, Mentor Graphics, Panoramic Tech, Photronics, Qualcomm, SanDisk and Tokyo Electron.