Using a 193-nm inspection tool for multi-layer mask blank inspection

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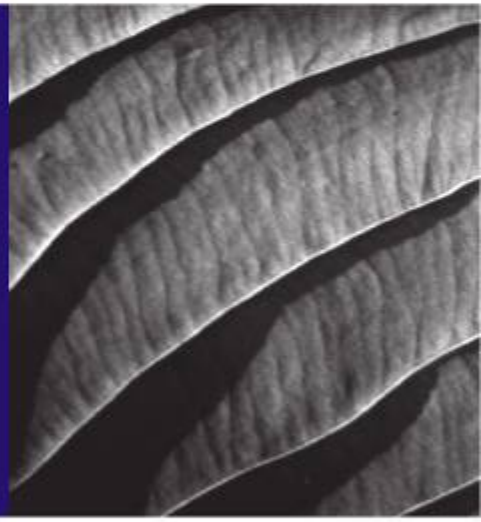

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Ted Liang, Andy Ma

A 193-nm inspection tool will speed EUV mask blank development.

Our inspections and image captures of defects on multi-layer (ML) EUV blanks indicate that:

- Sensitivity and throughput are better than available and planned tools
- Expected to meet 22-nm hp requirements
- Doesn't damage the mask (imager has low power density)
- Can measure surface roughness within our optical band (~0.5 μm^{-1} to 5 μm^{-1})
- Creative solutions to meet the business model challenges for blank inspection need to be discussed

- Caveat: 193-nm imaging is only affected by surface or near-surface variations in planarity or material variations. 193-nm light penetrates to a maximum of 3 to 4 layers deep. These surface defects might be the only ones that print.

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We captured through-focus images of natural defects on a characterized SEMATECH-AGC blank.

- The LM 7360 found natural defects
- An indenter marked 26 defect locations
- LBNL captured through-focus images on the AIT
- Sematech captured AFM images
- KT captured the through-focus images of the 26 defects on a Teron™ 610, EUV Blank Mode. All images captured at normal inspection speed.
- Images shown here are interpolated and only noise-filtered beyond the optical cutoff, retaining full optical resolution
- Signal values ($\Delta I / I$) shown are % of ML intensity; signal-to-noise (SNR) shown is after algorithm processing
- Teron 610 images compared with actinic images from the AIT (LBNL)

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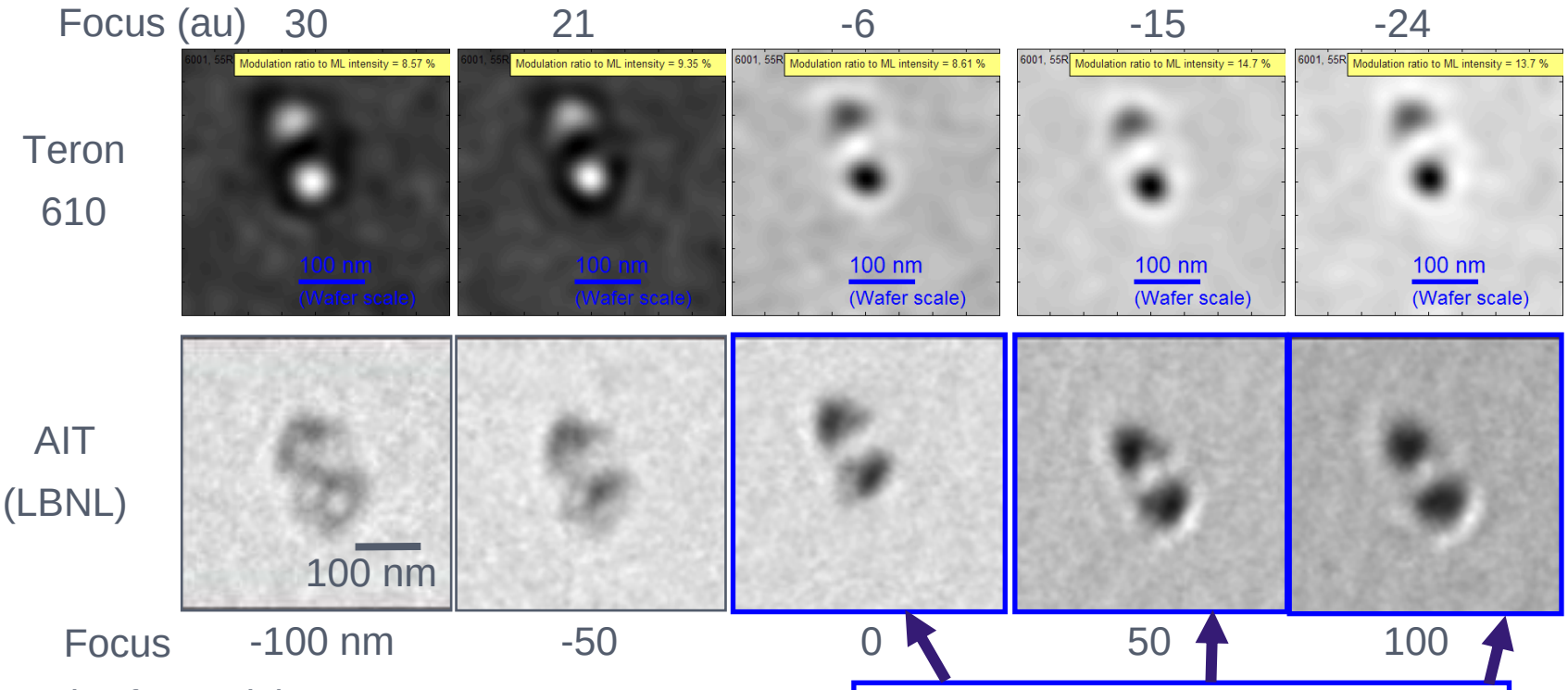
Defect A (>2 particles, 9.5 nm high x 55 nm FWHM)

Peak 193 nm raw signal = 14.7 % (100% = reflectance from multi-layer)

Signal-to-noise (SNR) = 50.0



$I_{actinic}$ < 40% at these focal positions

Printable as isolated defects

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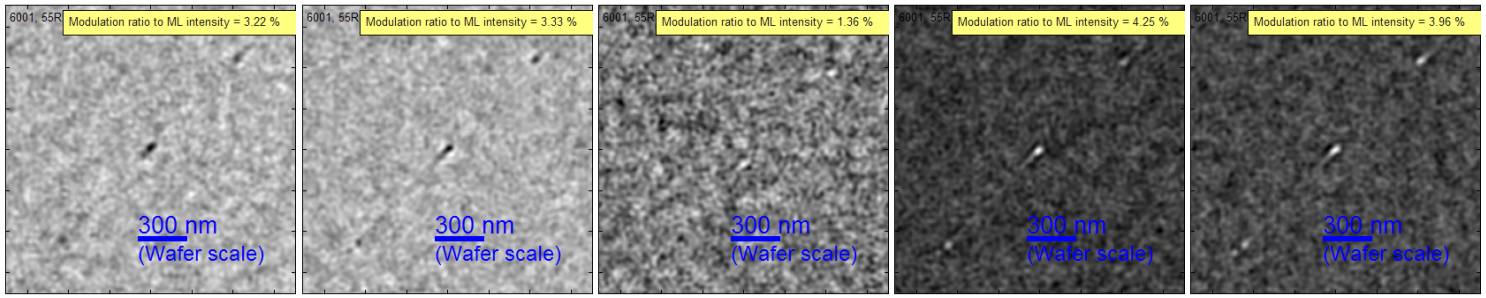
Defect N (scratch, 2.0 nm x 108 nm)

Peak DUV raw signal = 4.3 %

SNR = 13.3

Focus (au) 30 21 -6 -15 -24

Teron 610



AIT (LBNL)

Focus (wafer scale) -100 nm -50 0 50 100

$I_{actinic}$< 40% at all focal positions

Not printable as isolated defects

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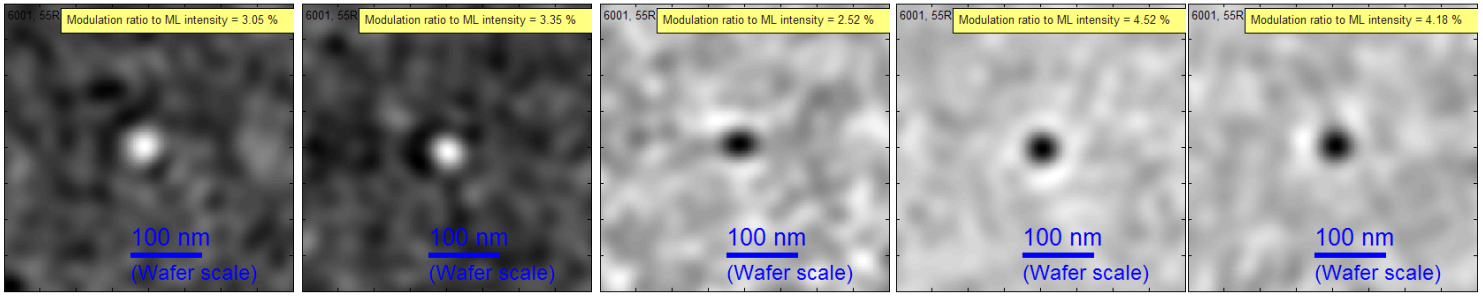
Defect V (bump, 2.7 x 70.7 nm)

Peak DUV raw signal = 4.5 %

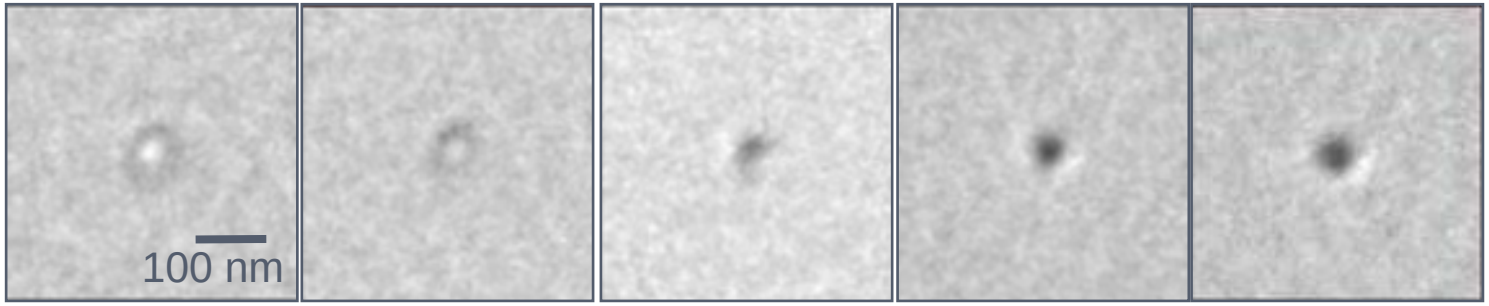
SNR = 16.8

Focus (au) 30 21 -6 -15 -24

Teron 610



AIT (LBNL)



Focus (wafer scale) -100 nm -50 0 50 100

$I_{actinic}$> 40% for all focal positions

Not printable as isolated defects

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Defect S (pit, 3.7 x 45.4 nm)

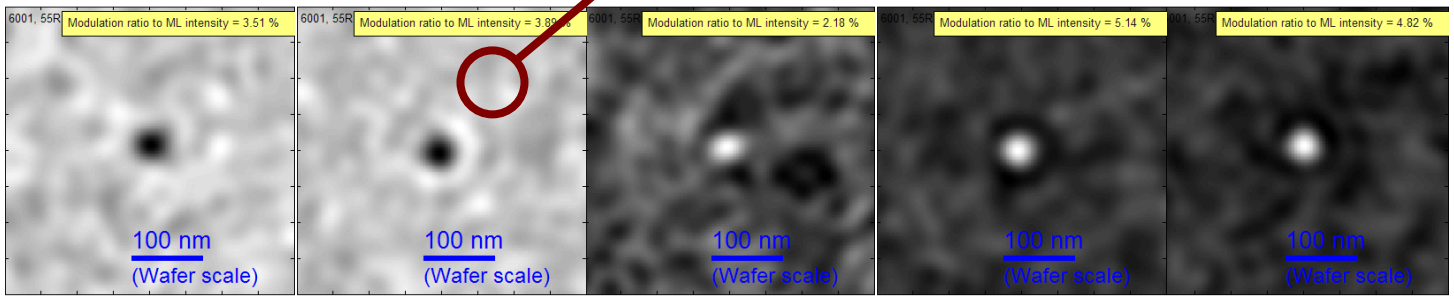
Peak DUV raw signal = 5.1 %

SNR = 19.2

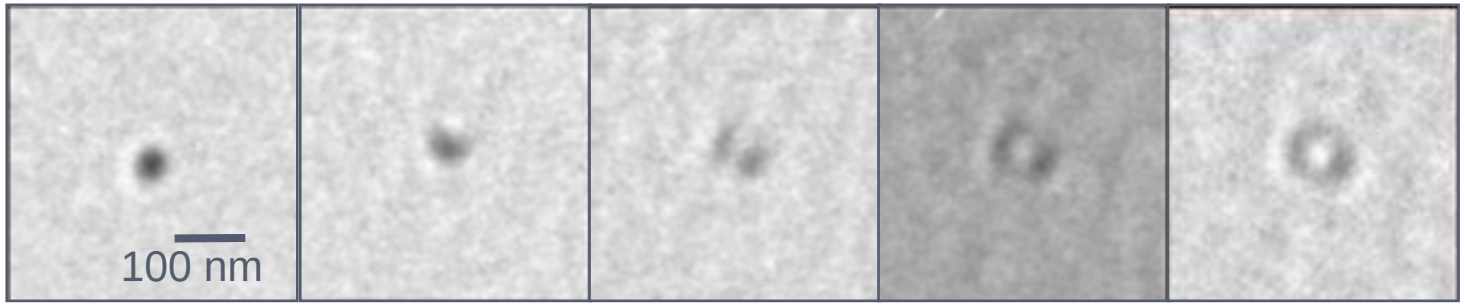
Roughness and tool noise

Focus (au) 30 21 -6 -15 -24

Teron 610



AIT (LBNL)



Focus (wafer scale) -100 nm -50 0 50 100

$I_{actinic}$> 40% for all focal positions

Not printable as isolated defects

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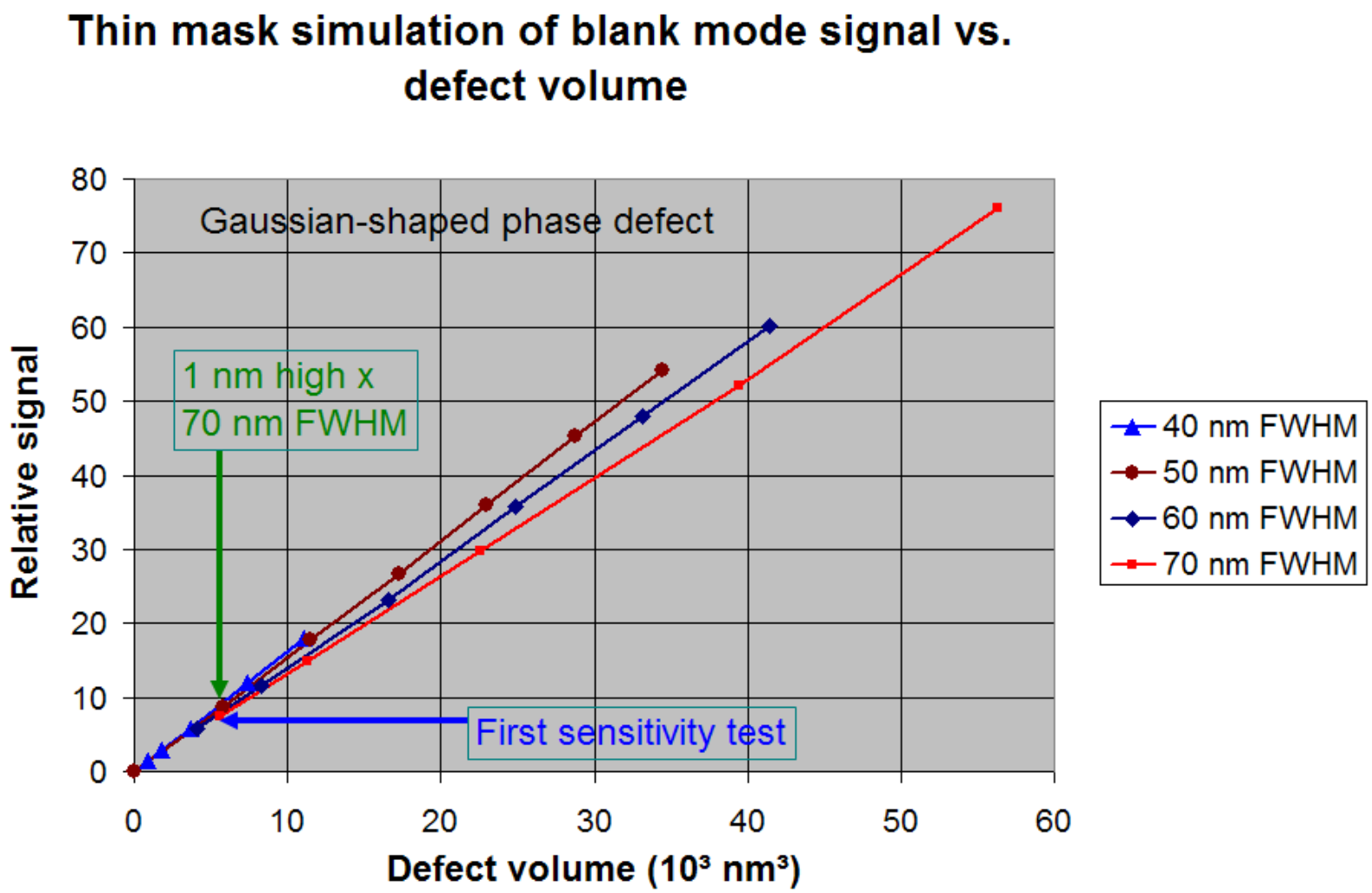
Small defect image signal is ~linearly proportional to defect volume (makes sizing easy).



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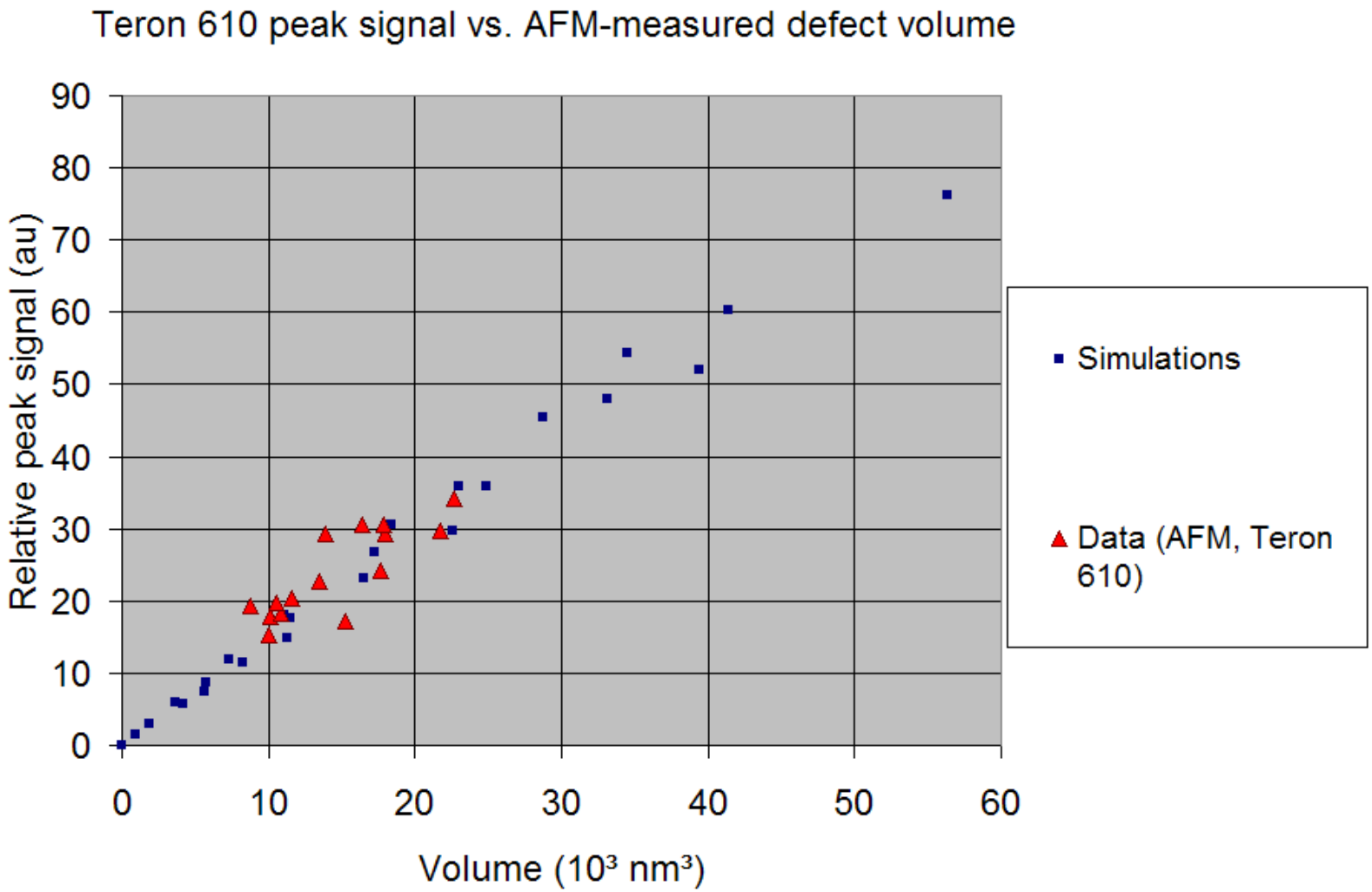
Peak signal vs. the AFM-measured sizes are well-correlated to our simulations.



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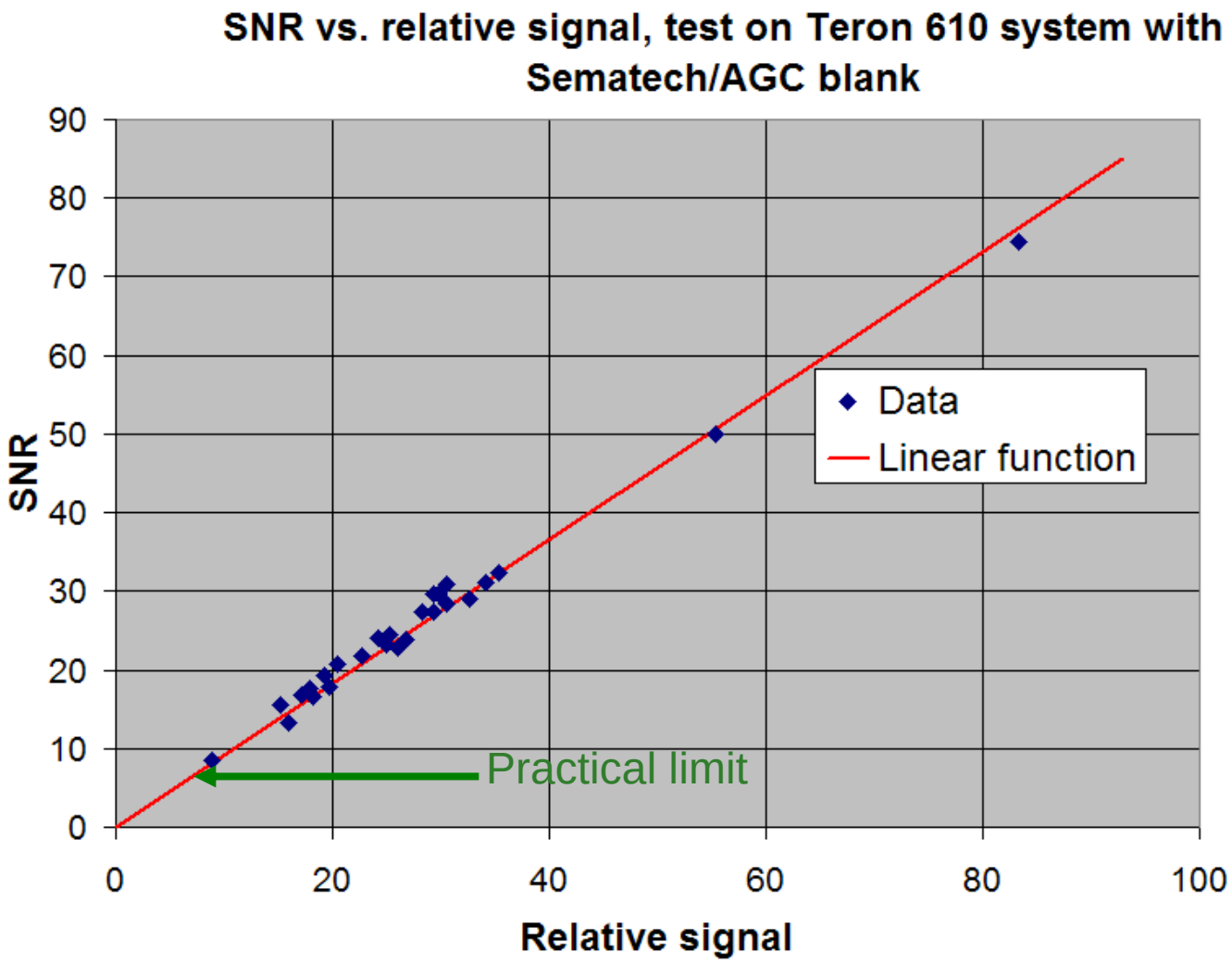
SNR of the 26 defects shows additional sensitivity in Blank Mode.



Improved Blank Mode version now being tested

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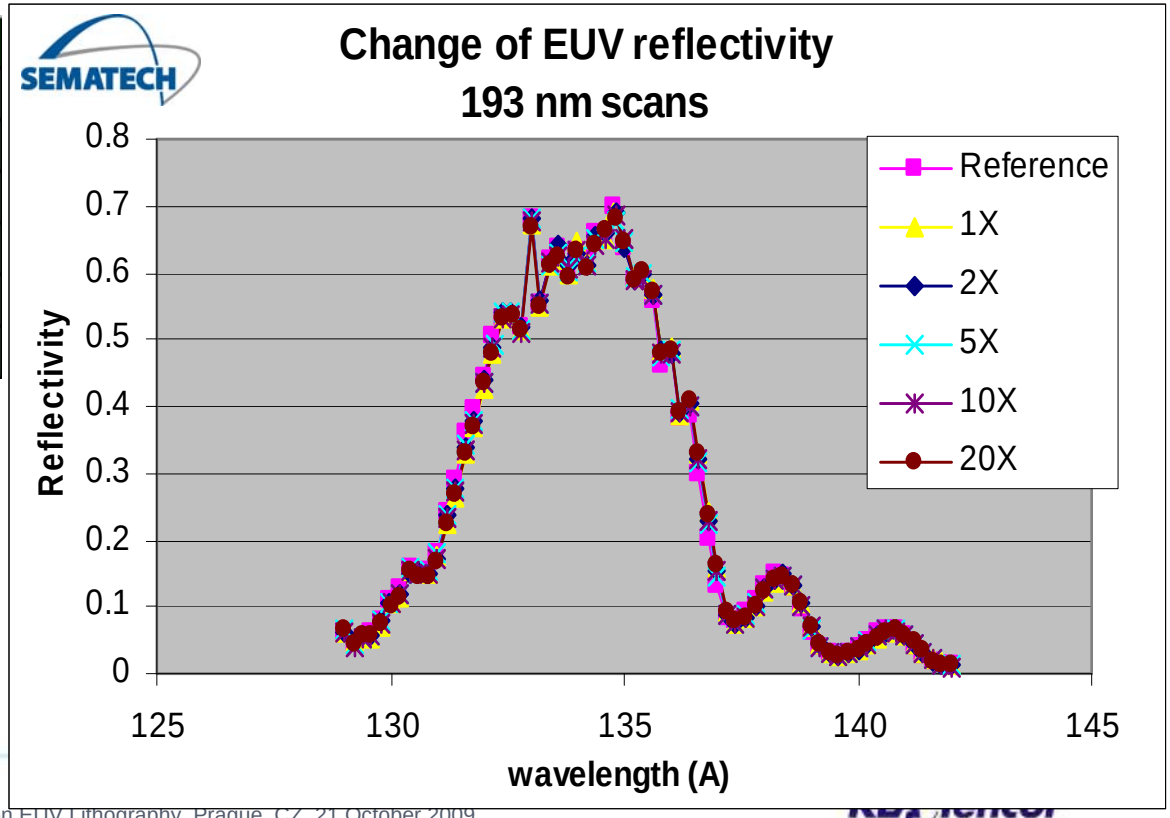
Teron 610 imaging approach does not damage the multi-layer.

1, 2, 5, 20 (50) full power scans of 1 cm² areas of Si-capped and Ru-capped ML blanks show no evidence of damage. (Many thanks to C. C. Lin of Sematech for the analyses)

- Sematech MBDC analysis (EUV reflectivity and XRR)

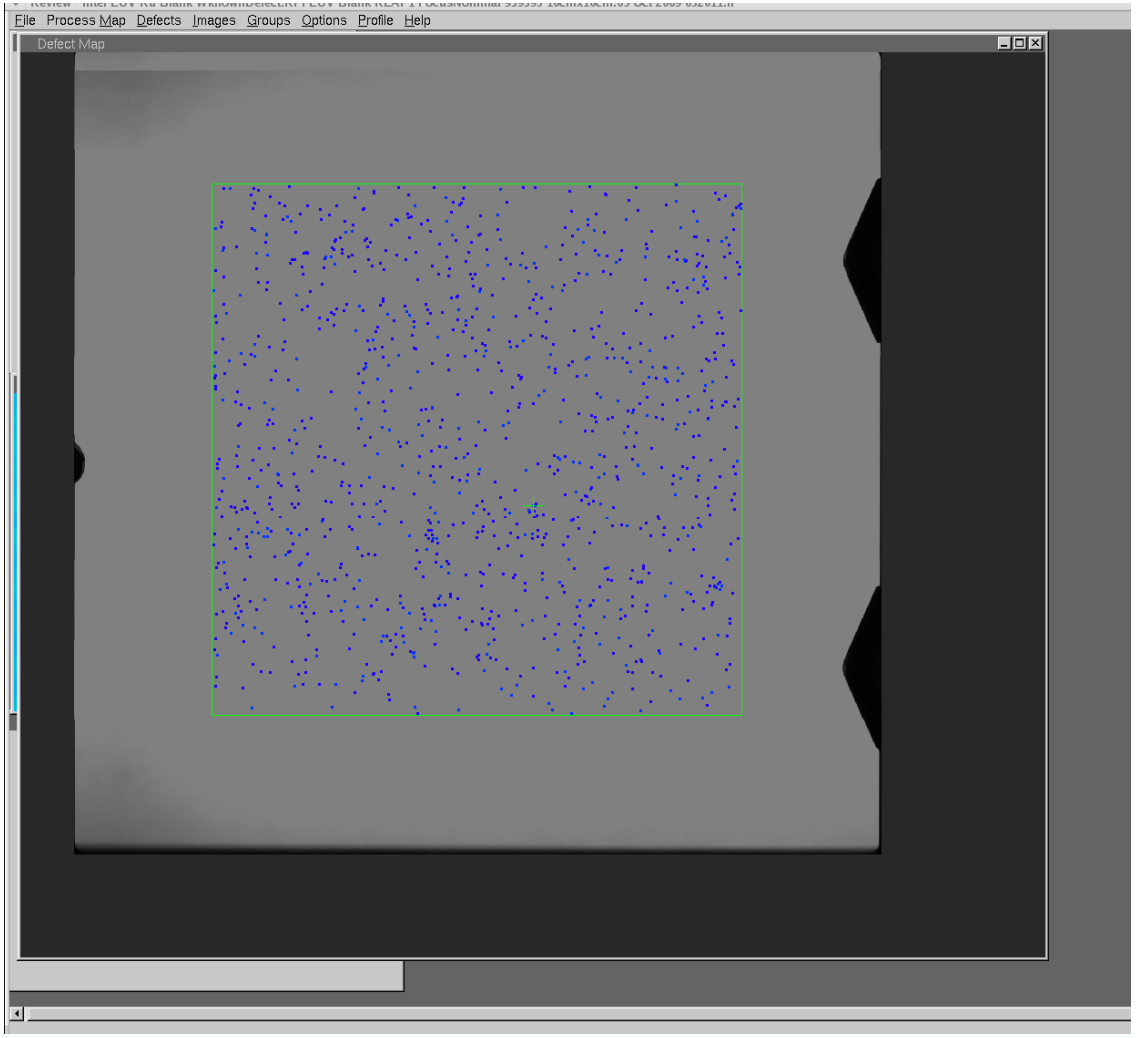
SEMATECH	Rmax	FWHM	Centroid
Before	65.3%	4.938	134.019
1X	65.2%	4.936	134.128
2X	65.3%	4.937	134.091
5X	65.0%	4.959	134.078
10X	64.8%	4.919	134.099
20X	64.9%	4.937	134.123

EUV reflectivity and XRR show no measureable damage



We are using a Teron 610 to inspect EUV ML blanks.

Defect map of natural defects on an EUV ML blank



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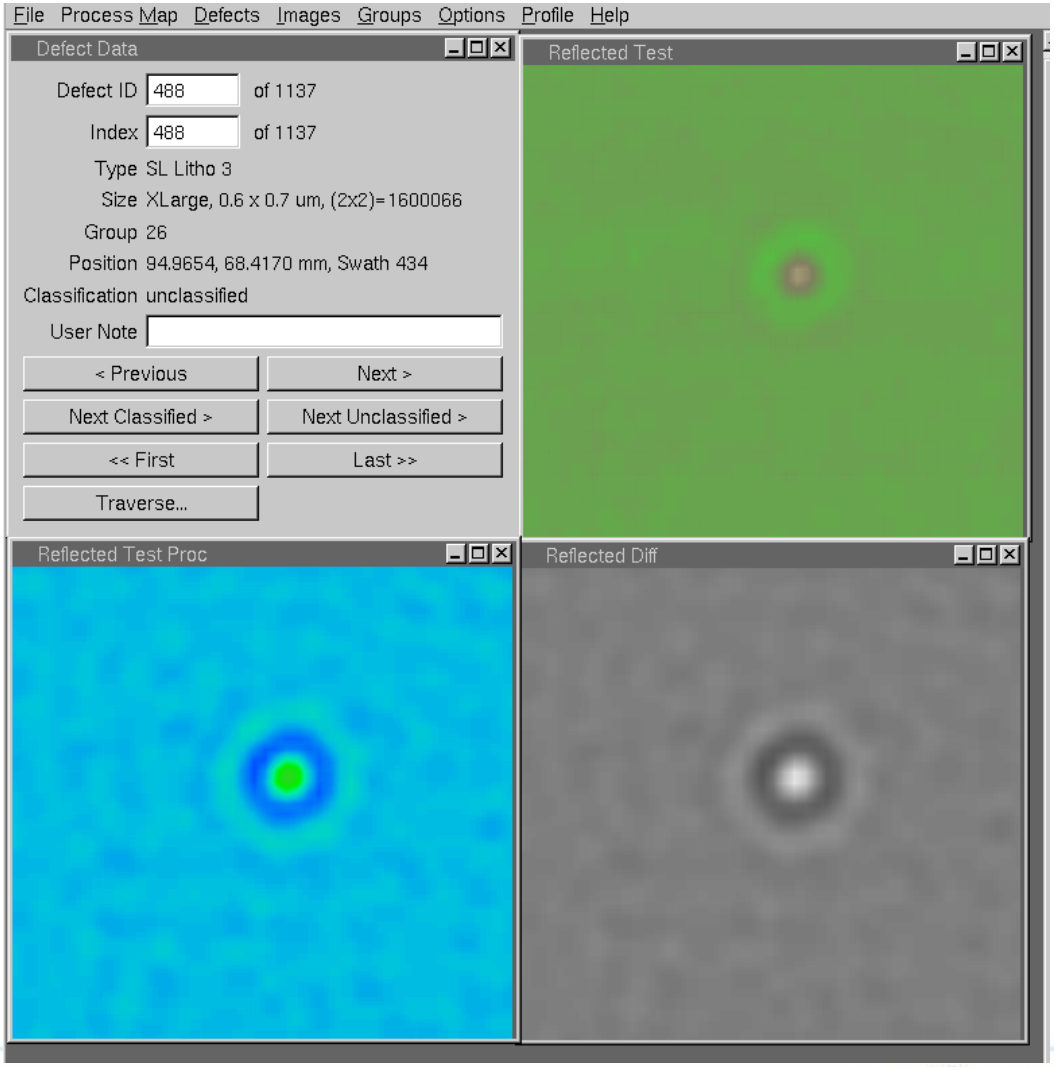
We are detecting phase defects.

- This defect is a pit
- Pits are bright; bumps and particles are dark in Blank Mode

Note:

- Amplitude defects also have contrast in Blank Mode



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A second version of our Blank Mode finds 1-nm high bumps at 70% capture rate.

- With a second version of Blank Mode we are determining our signal levels, SNR, and capture rates on a programmed defect mask
  - Awaiting final AFM data; will compare with simulations
- Initial results are very promising
  - 1 nm x 90 nm FWHM bump array has 70% capture rate
- Surface roughness of this mask contributes ~44% to the image noise variance
- In parallel we are developing improved algorithms and optical modes for increased sensitivity
- Blank Mode not yet commercially available

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Our 193-nm inspection tool will speed EUV mask blank development.

- Sensitivity and throughput are better than available and planned tools. Expected to meet 22-nm requirements
- Blank mode available < 1 year vs. production actinic > 4 years in the future
- Sensitivity improvement path available with field-upgrades of tool
- Doesn't damage the mask (imager has low power density)
- Can measure surface roughness within our optical band (~0.5 μm^{-1} to 5 μm^{-1})
- Creative solutions to meet the business model challenges for blank inspection need to be discussed

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