Correlation depth analysis of surface roughness by actinic blank inspection

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Outline

1. Introduction
2. Correlation depth analysis
3. Estimation of wafer impact
4. Summary

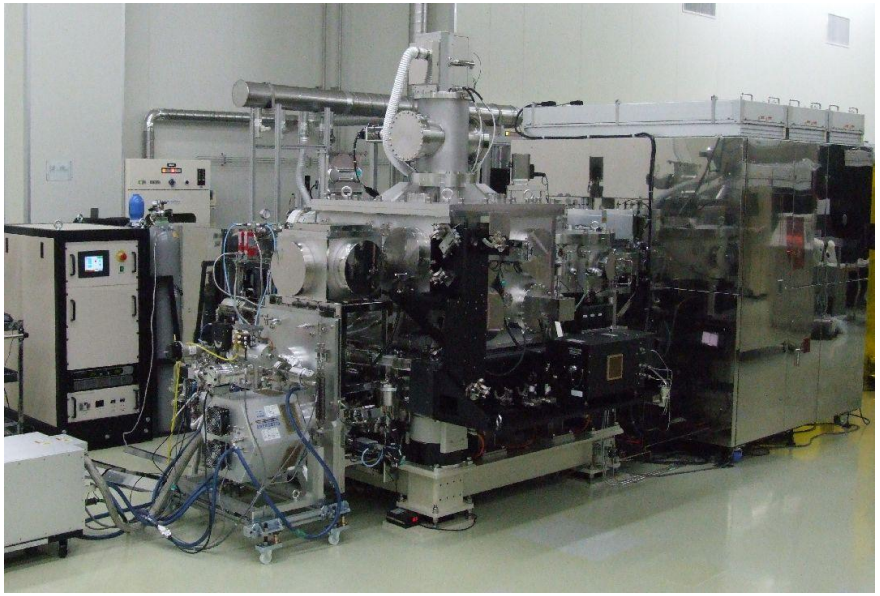
Outline

Actinic blank inspection (ABI) tools

MIRAI-tool
(Full-field inspection prototype)

Developed by Selete and EIDEC
Available since August, 2008

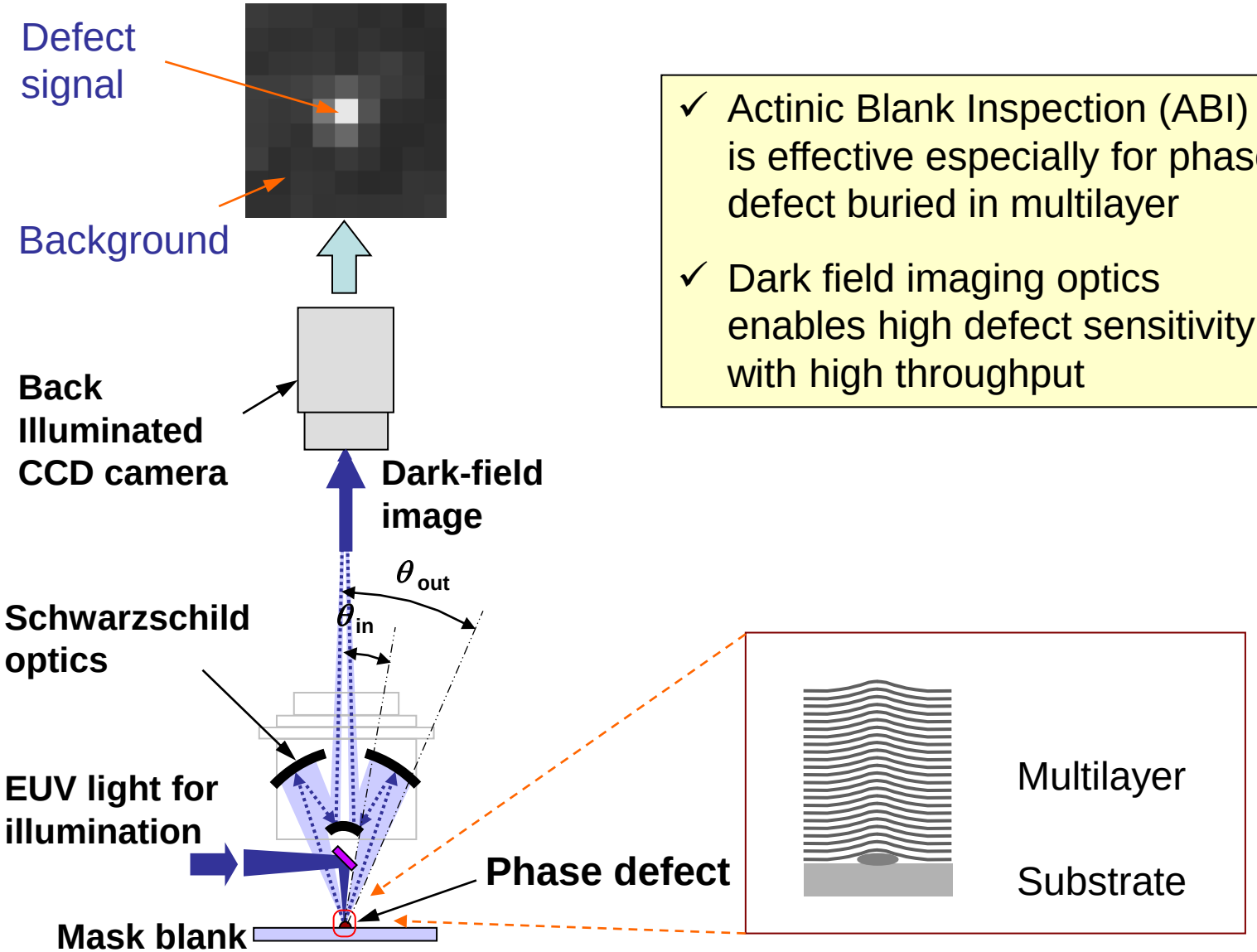
HVM prototype *



Developed by Lasertec and EIDEC
Available since December, 2012

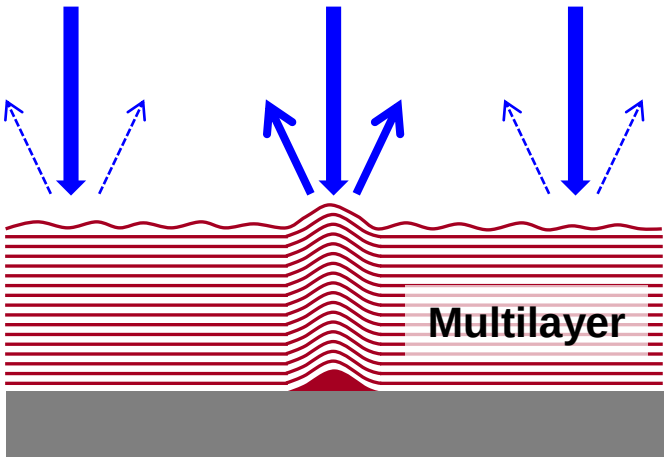
*) T. Suzuki, “High Magnification Review Function for Defect Location Accuracy Improvement with EUV Actinic Blank Inspection Tool,” 2013 International Symposium on Extreme Ultraviolet Lithography

Schema of Actinic Blank Inspection

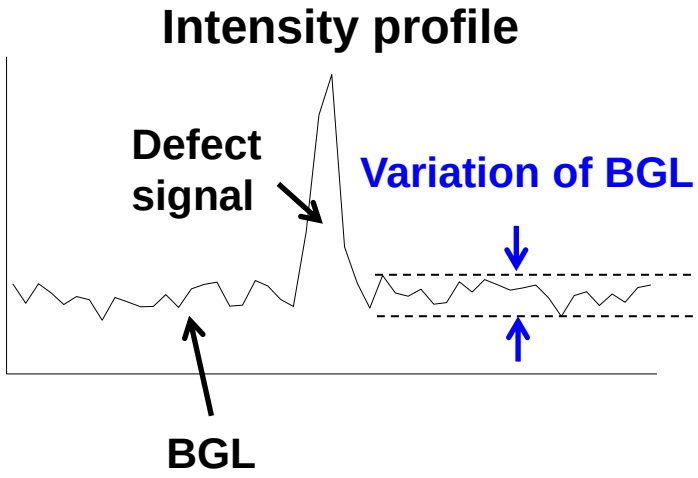


- ✓ Actinic Blank Inspection (ABI) is effective especially for phase defect buried in multilayer
- ✓ Dark field imaging optics enables high defect sensitivity with high throughput

Background level variation on ABI image



Background level (BGL) is caused by a scattered light from multilayer (ML) surface roughness



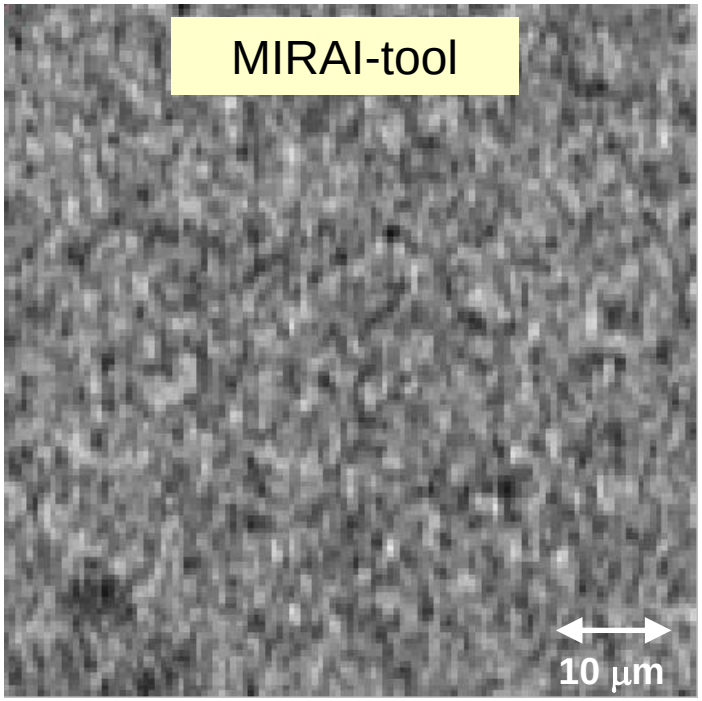
Variation of BGL

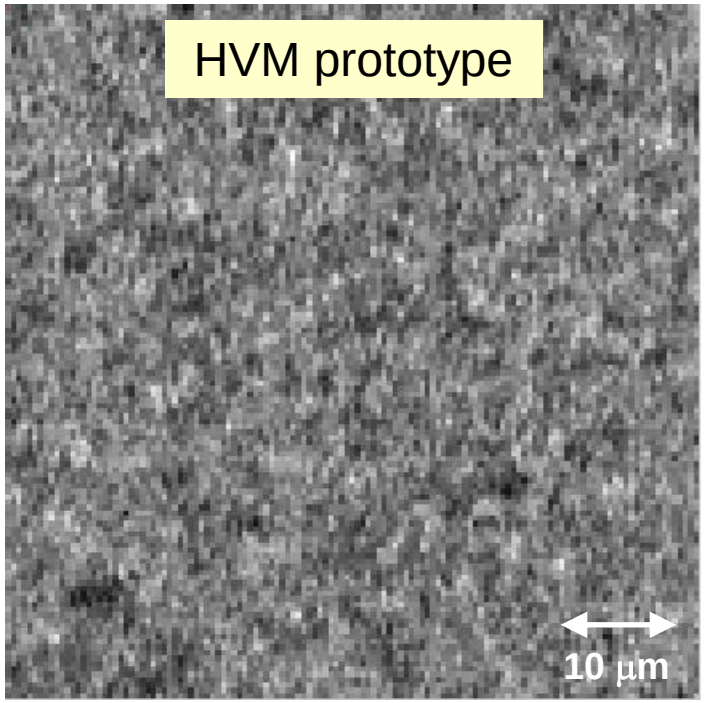
Random factor

- Tool's factor
  - Shot noise
  - Light source fluctuation
  - Non-uniformity of CCD sensitivity
  - Lens aberration
- Mask's factor
  - Local variation of ML roughness
  - Speckle pattern due to ML roughness

Averaged BGL images with two ABI tools

BGL images were captured 20 times and averaged





Similar patterns were observed → Mask's factors

The BGL images were reproduced by simulation with AFM, and correlation depth of surface roughness was estimated

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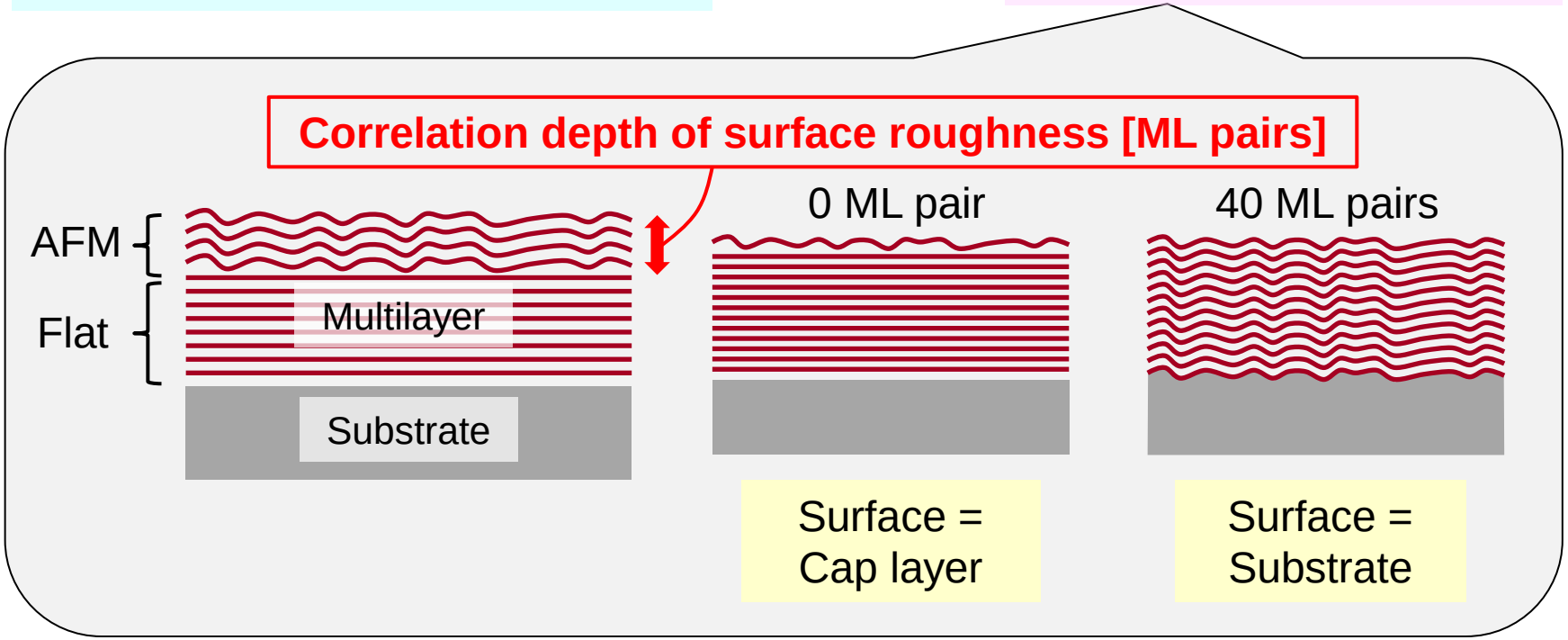
Methodology

Actual BGL images
Non-defect area was captured 20 times with MIRAI-tool

Comparison

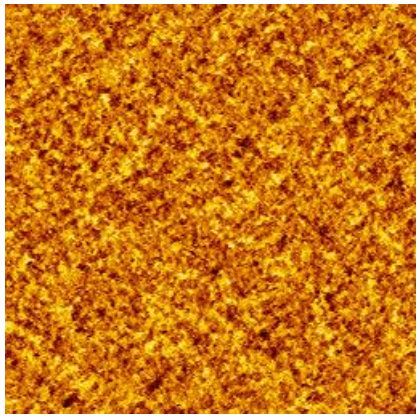
Simulated BGL images
- AFM measurement
- Correlation depth

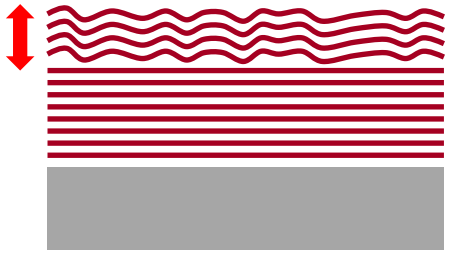


- ✓ ***With variation of correlation depth, the BGL images were simulated***
- ✓ ***Correlation depth was determined so that the simulated BGL image could be the best corresponding to the actual BGL image***

Simulated BGL image with AFM measurement

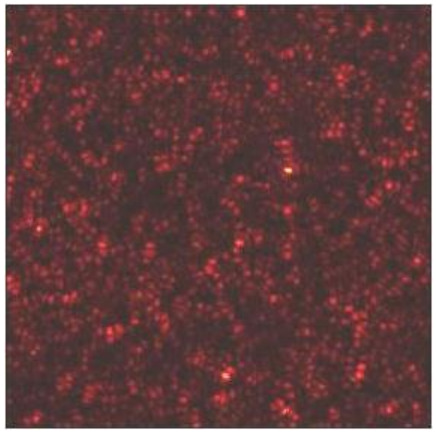
AFM image





Correlation depth

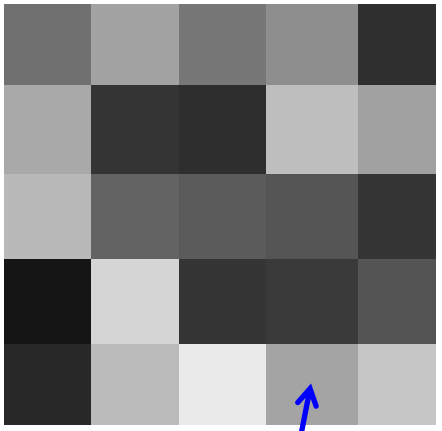
Simulated image at AFM grid size



Optical parameters of ABI
NA 0.27, sigma 0.2
Circular illumination

Grid size 10 nm

Simulated image at ABI pixel size

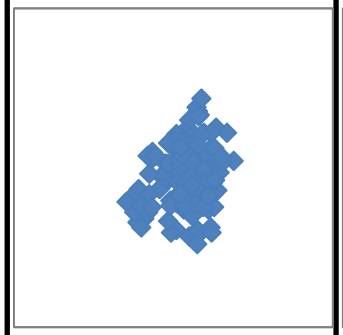
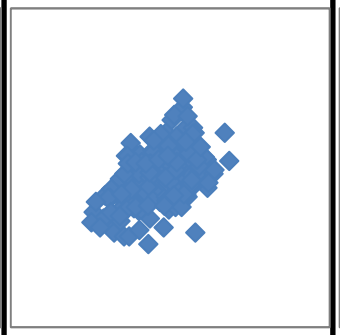
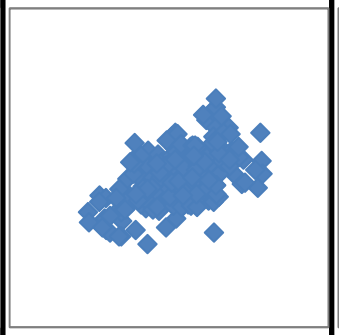
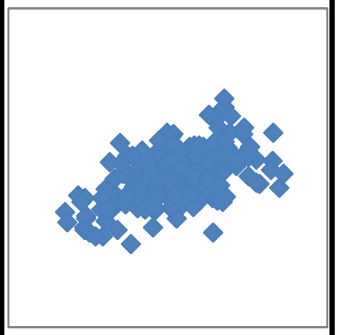
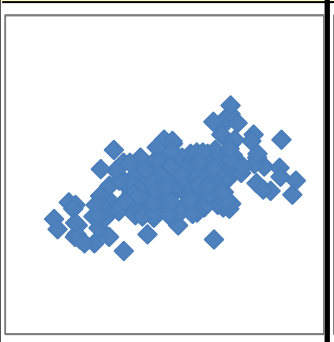
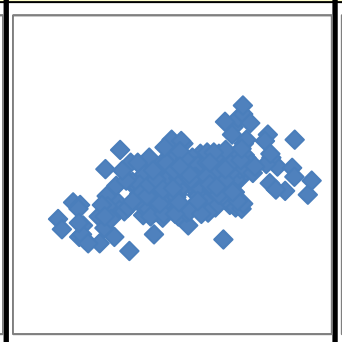
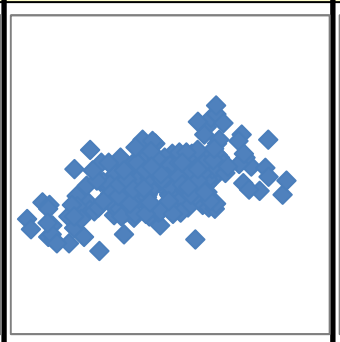
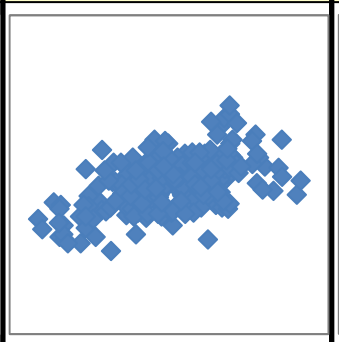
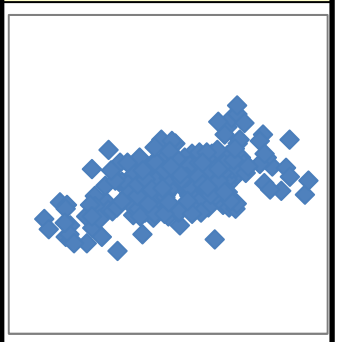


BGL intensity

Pixel size 0.5 μm

Comparison of BGL intensities

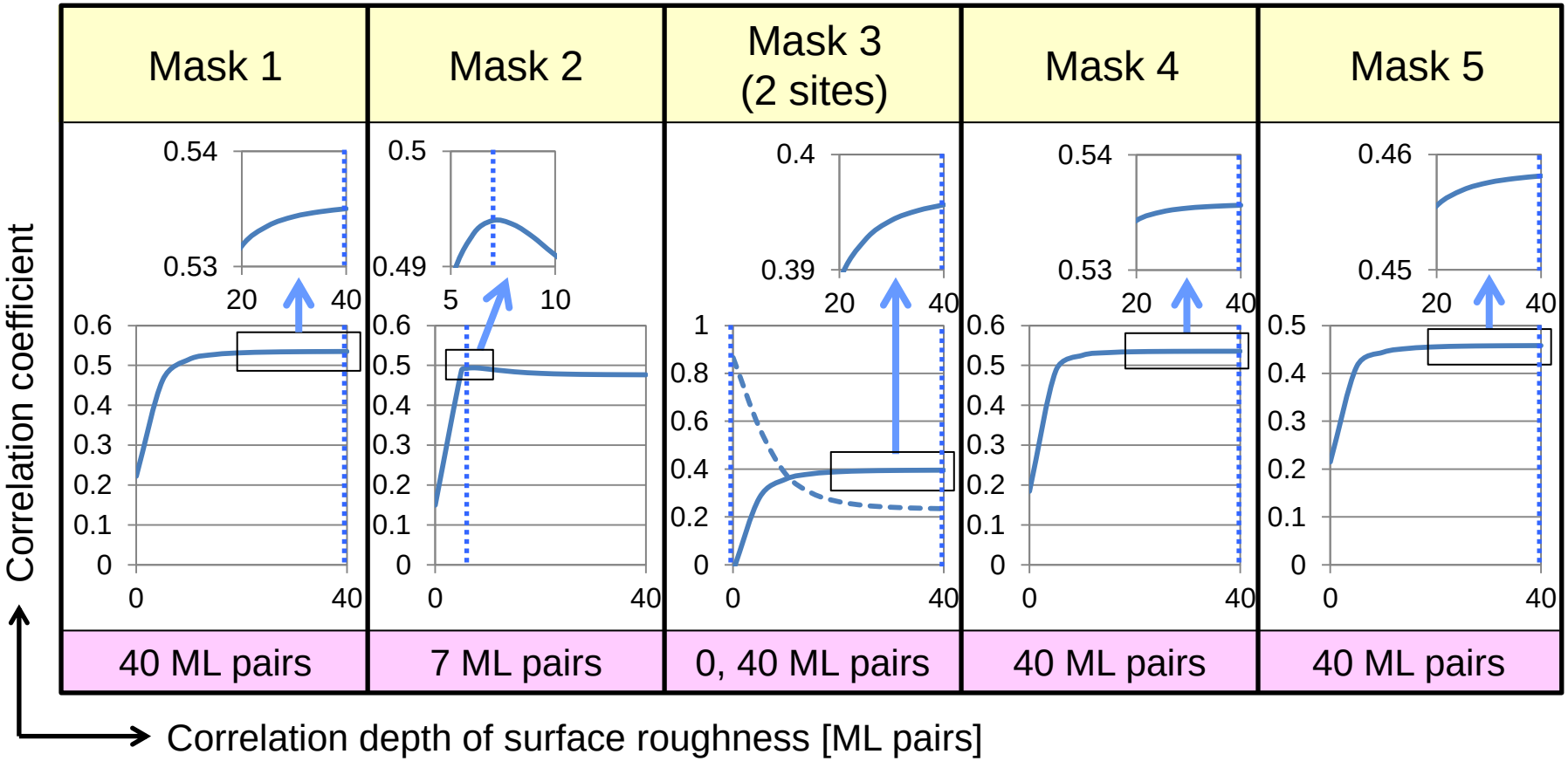
BGL intensities on the actual image

Correlation depth	0 ML pair	5 ML pairs	10 ML pairs	15 ML pairs
				
Correlation coef.	0.2221	0.4630	0.5151	0.5275
20 ML pairs	25 ML pairs	30 ML pairs	35 ML pairs	40 ML pairs
				
0.5318	0.5335	0.5343	0.5348	0.5350

BGL intensities on the simulated image

Correlation depth analysis

6 sites (10 μm x 10 μm area) on 5 masks were evaluated



The correlation depths depended on masks and sites on a mask

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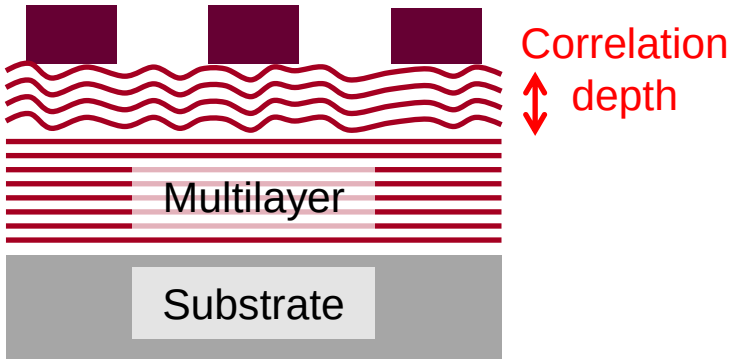
Simulation of wafer image

Wafer images of 10 masks were simulated using AFM measurement with variation of the correlation depths

Mask structure

- ML structure
  - Surface: AFM measurement
  - Under the correlation depth: Flat
- The correlation depth: 0 – 40 ML pairs
- Pattern size: 64 nm L/S pattern on 2.56 x 2.56 μm area (16 nm node)



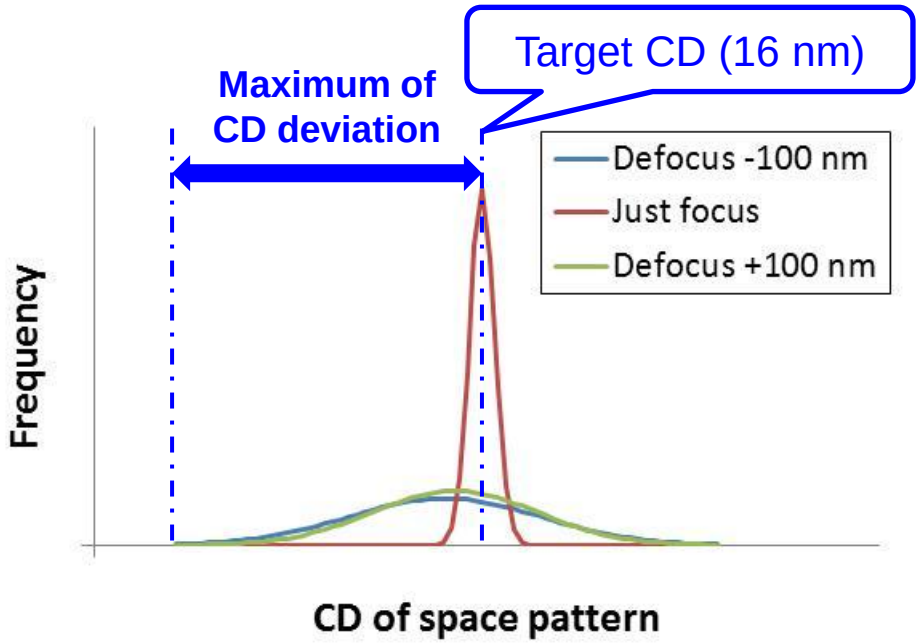
Exposure condition

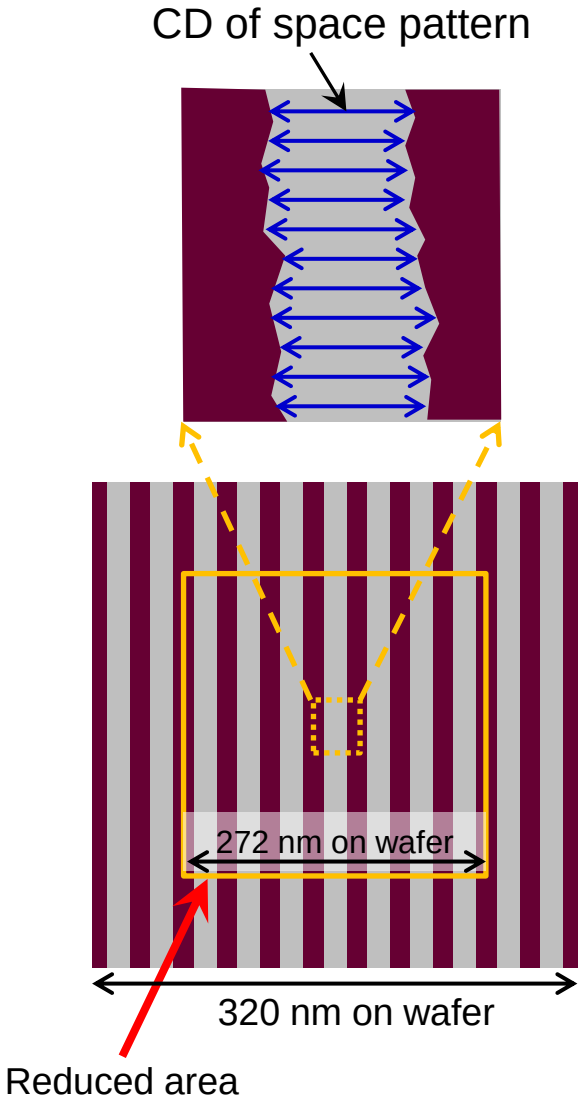
NA 0.33, Dipole (σ=0.4/0.8), Open angle 90 deg.,
Defocus -100 nm, 0 nm, +100 nm

Wafer images were simulated by DPS (Luminescent Technologies, Inc.)

CD deviation of simulated wafer image

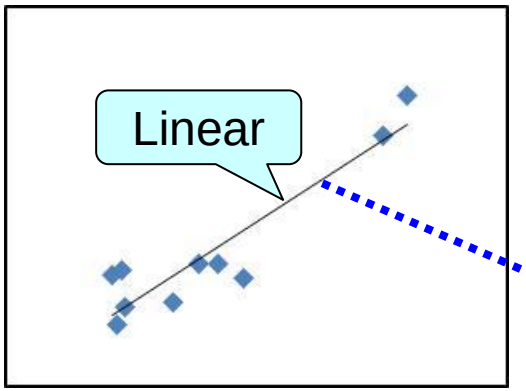
- CDs of space patterns in the reduced area of wafer images were measured
- Threshold for CD was determined with the just-focus image
- The maximum of CD deviations on each of mask was obtained

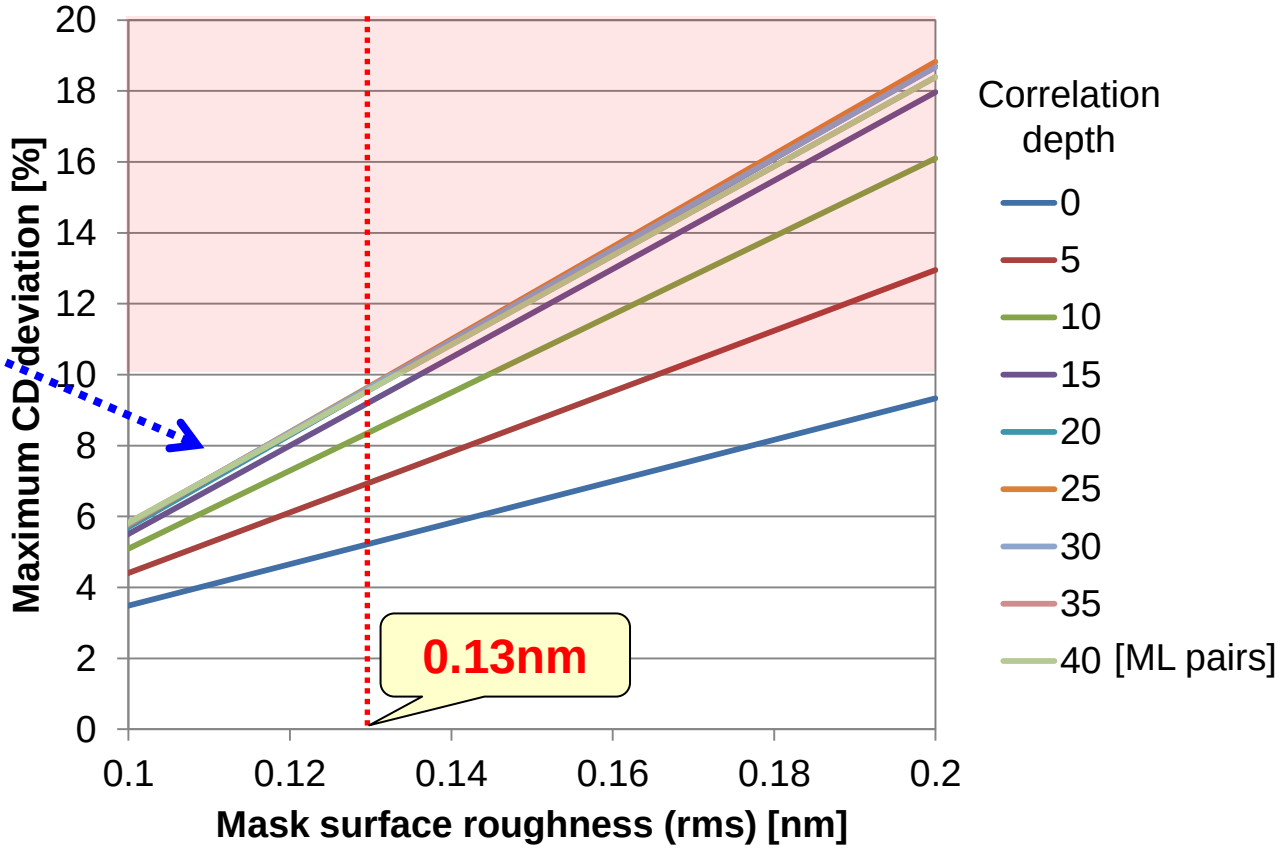




Estimation of wafer impact

- ✓ The maximum CD deviations of 10 masks were calculated.
- ✓ The rms value of mask surface roughness were measured by AFM





In the case of correlation depth deeper than 20 ML pairs, mask surface roughness of 0.13 nm rms became critical for 16 nm node when the evaluation area was 1 x 1 μm on a mask

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2. Analysis of background level variation
3. Estimation of wafer impact
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Summary

- It was demonstrated that correlation depth of mask surface roughness was estimated with the actinic blank inspection (ABI).
- As the result, the correlation depths depended on masks and sites on a mask.
- As the result of wafer impact estimation, the deeper a correlation depth is, the more a wafer CD deviates.

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