Measurement accuracy of phase defect size on EUV mask

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Summary and conclusion

- Measurement repeatability of the phase defect using SPM was examined.
- Variation of the defect-to-defect volume was much larger than measurement repeatability.
- Measuring volume of each phase defect is essential to evaluate the defect detection yield using inspector.
- ABI HVM could predict the defect volume roughly from the defect signal intensity (DSI) even though the defect signal intensity itself have variation.

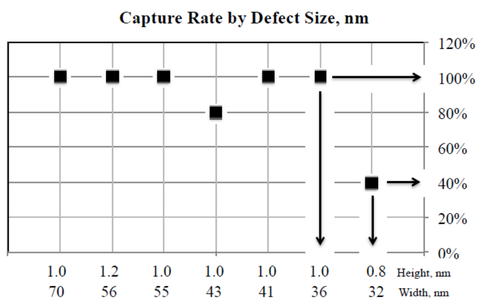
Introduction

In this study, measurement repeatability of the phase defect volume using scanning probe microscope (SPM) and influence of the defect volume distribution on defect detection signal intensity using at-wavelength dark-field defect inspection system (Actinic Blank Inspection, (ABI), High Volume Manufacturing (HVM) model) were examined.

Motivation

Why ABI failed to catch phase defect?

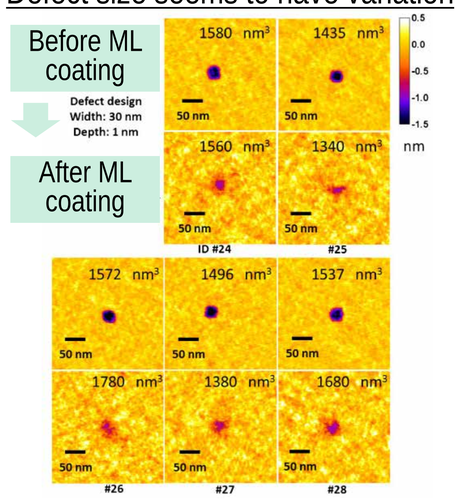
ABI HVM result shared by Lasertec



A. Tchikoulaeva et al., Proc. SPIE 8679, 86790I (2013)

- The undetected 1.0 nm-high and 43 nm-wide had lower DSI than neighbors, but the defect size measured using SPM was almost same.

Defect size seems to have variation



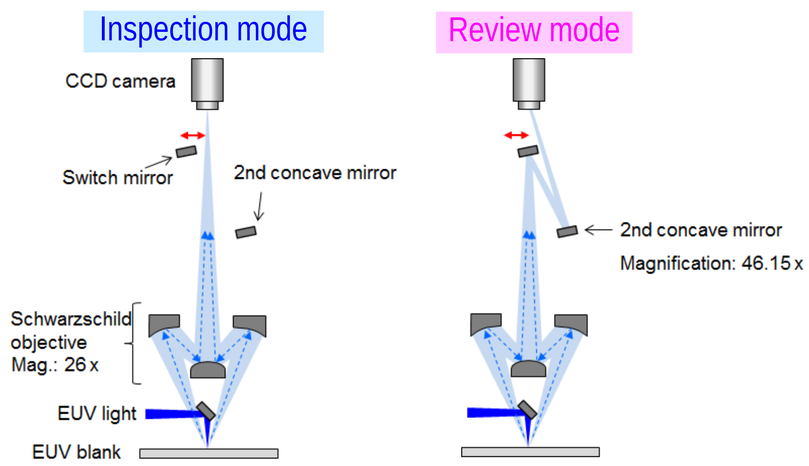
Y. Tanaka et al, Jpn. J. Appl. Phys. 53, 06JC03 (2014)

- The seeds are similar in shapes.
- Different shapes after coating the multilayer.

Influence of the defect size variation on DSI was examined.

Phase defect volume vs. ABI DSI

ABI HVM model — DSI (Defect Signal Intensity)



	Inspection mode	Review mode
Magnification:	26 X	1200 X
Pixel size at blank plane :	462 nm	10nm

Imaging with the review mode, influence of the ML roughness on DSI can be eliminated due to small pixel size. See Yamane's work "PMJ2014".

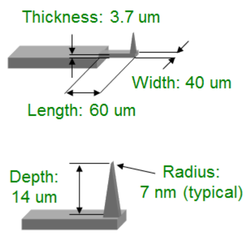
Measurement repeatability of the phase defect volume using SPM

SPM

L-Trace II

Cantilever

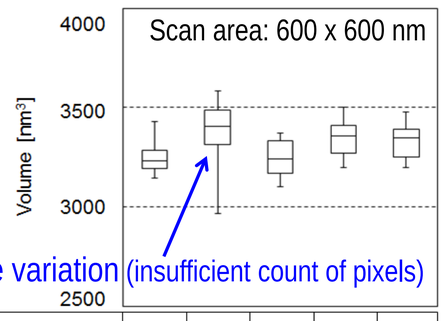
Model number: SI-DF40P2
K = 26 N/m, F = 250-390 kHz



Phase defects had taken their images with a combination of L-Trace II *) and SI-DF40P2.

*) Hitachi High-Tech Science Corporation former SII NanoTechnology Inc.

Optimization of the SPM pixel resolution

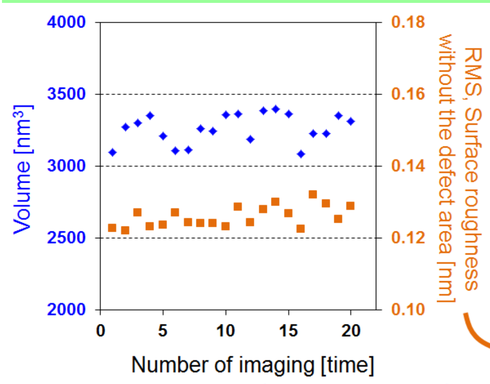


Imaging order		1	2	3	4	5
Number of pixels	X	512	512	512	1024	512
	Y	256	128	512	1024	256
Mean [nm³]		3248	3375	3247	3349	3336
3 sigma [nm³]		246	514	285	282	284

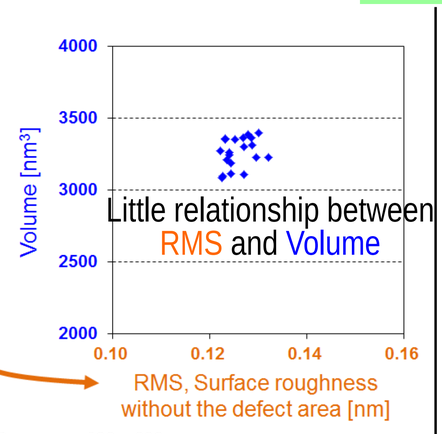
- Smaller number of scan lines is preferred to prevent tip damaging.
- X: 512, Y: 256 pixels were selected.

Measurement repeatability

1 tip 20 consecutive measurements

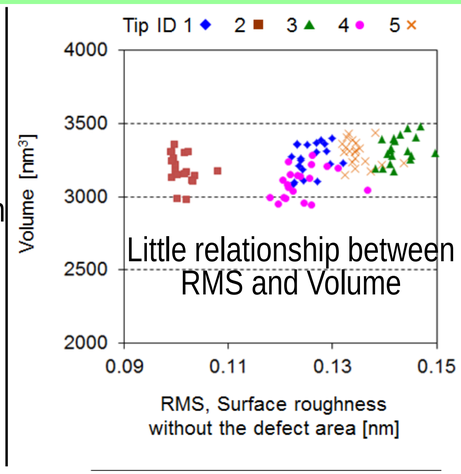


Mean: 3261 [nm3]
3 sigma: 309 [nm3]
SEVD: 18.4 [nm]
3 sigma: 0.6 [nm]



Scan area: 600 x 600 nm
Number of pixels: X 512, Y 256

5 tips, 20 consecutive measurements



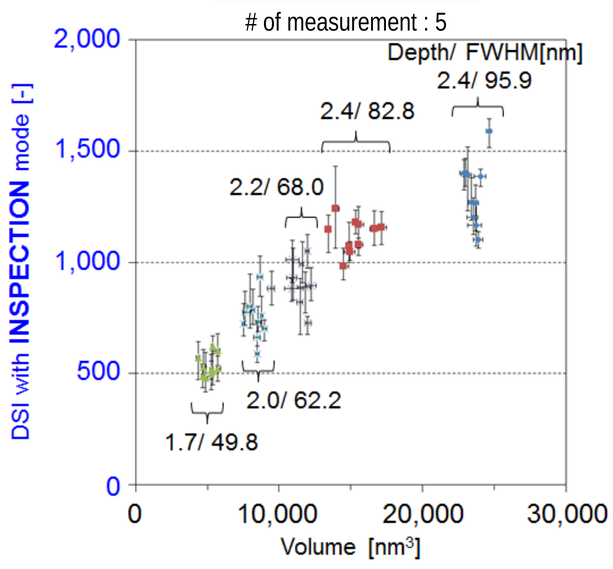
Tip ID	Volume Mean [nm³]	Volume 3 sigma [nm³]
1	3261	309
2	3194	306
3	3324	275
4	3096	309
5	3299	254

Mean: 3235 nm³
Pooled 3 sigma: 378 nm³

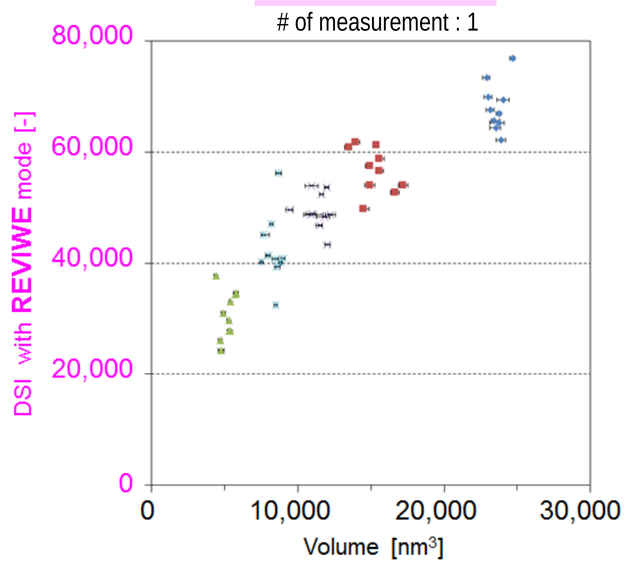
- There is no identifiable relationship between the measured surface roughness and measured volume; and that we cannot tell whether the tip is sharp or dull from the roughness value.

Relationship between defect volume and DSI

Inspection mode

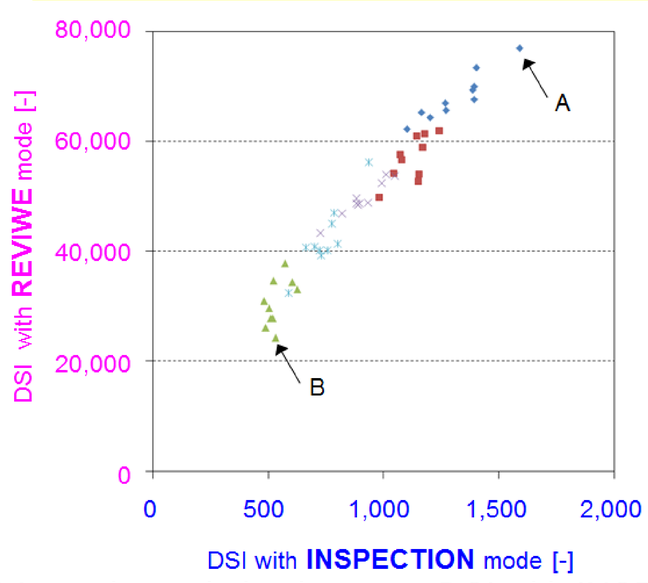


Review mode

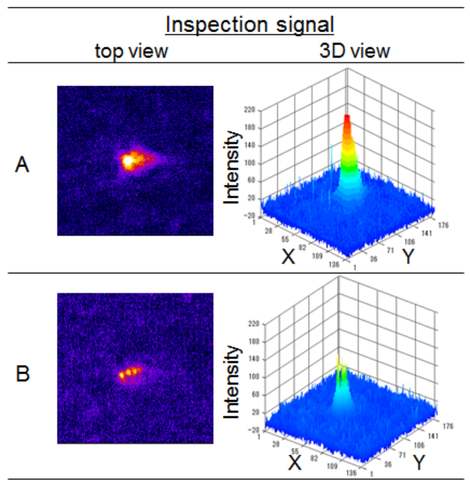


- The defect volumes can be roughly estimated from the DSIs even if the DSIs also seem to have variations.

Comparison of the two DSIs INSPECTION mode VS. REVIEW mode



Review images



- A good correlation between DSI with INSPECTION mode and REVIEW mode was observed.

== Future work==
Evaluation of the measurement repeatability of the DSIs taken by the review optics.
Impact of the defect volume distribution on the printability by a lithography simulator.

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