Defect detection sensitivity improvement of actinic blank inspection

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Outline

1. Introduction
2. Improvement of defect sensitivity
3. Evaluation of amplitude defect sensitivity
4. Summary

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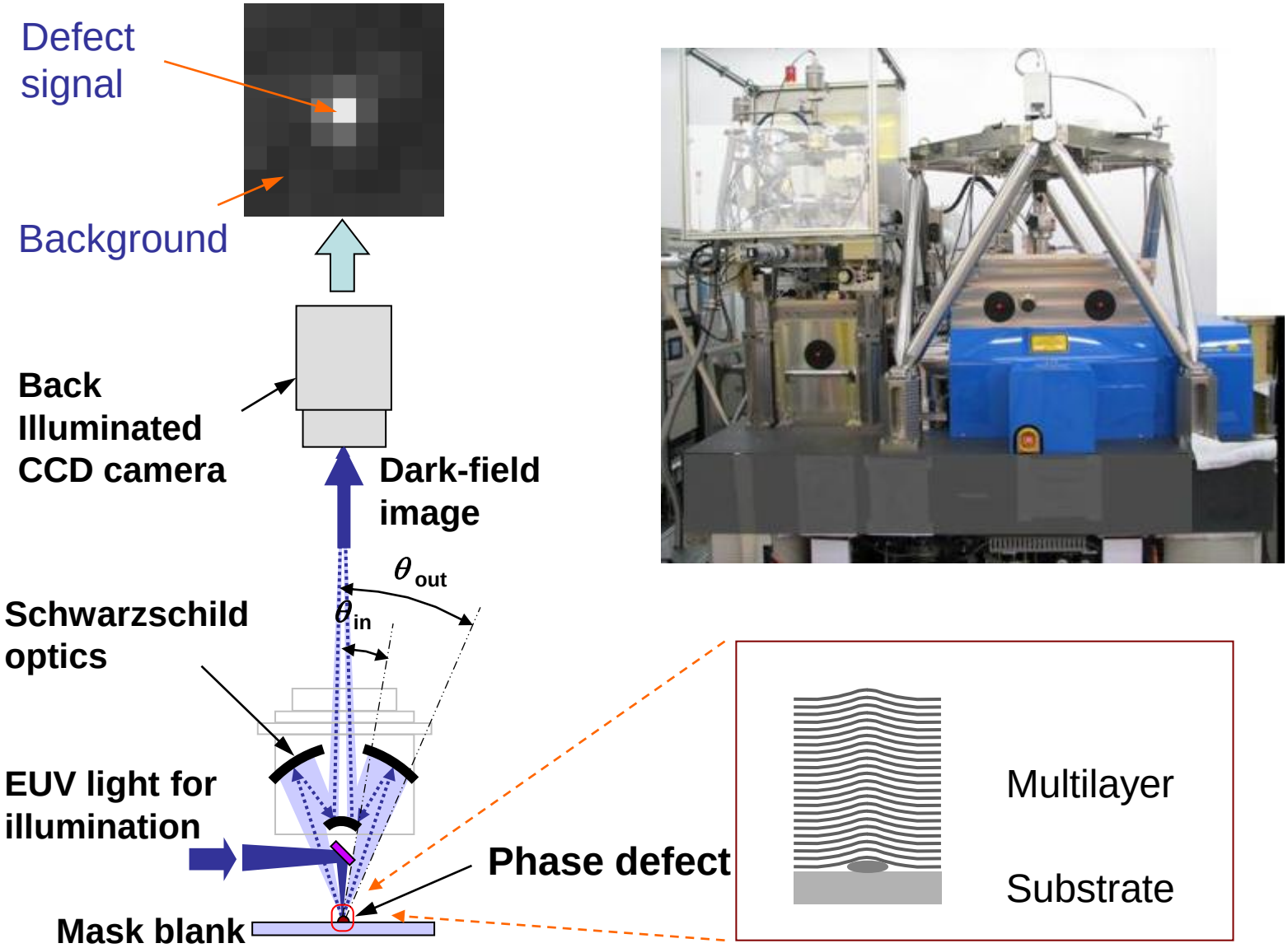
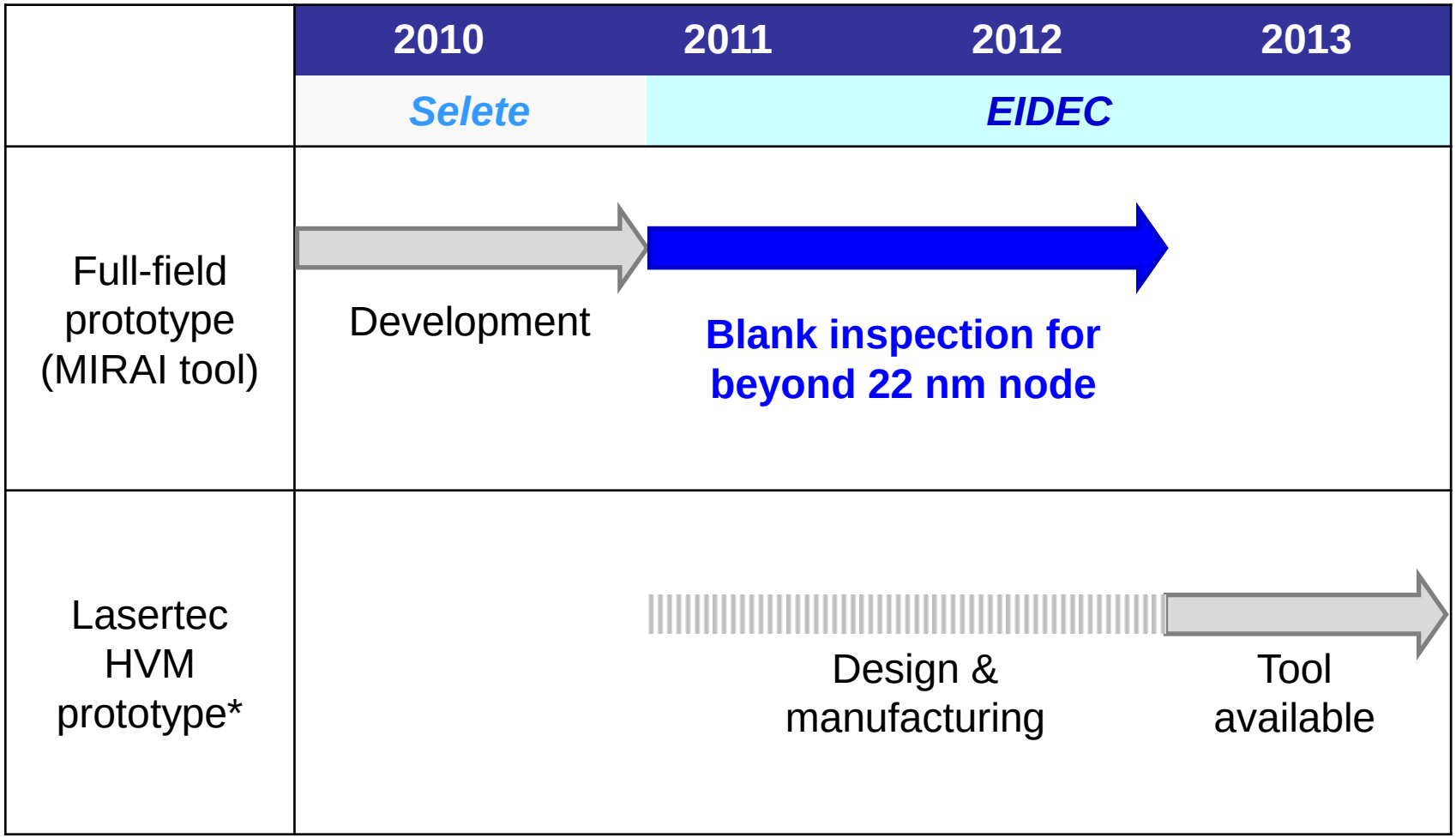
Schema of the actinic inspection system



Previous inspection capability

Scan speed		**3 mm/s**
Inspection time for full-field area		**4.8 hours**
Sensitivity	**Phase defect**	H 1.2 nm W 40 nm programmed defect **95% detection**
	Amplitude defect	Native amplitude defects higher than 30 nm with high detection probability **Not quantified**

EIDEC Blank Inspection Project



* Hiroki Miyai et al., "*EUV Actinic Blank Inspection Tool Development*," EUVL Symposium 2011

Purpose of this work

Improved items for beyond 22 nm node inspection

- ✓ Auto-focusing accuracy
- ✓ Defect detection algorism

This work

- ➢ Improvement of defect sensitivity was demonstrated
- ➢ Amplitude defect sensitivity was evaluated and analyzed

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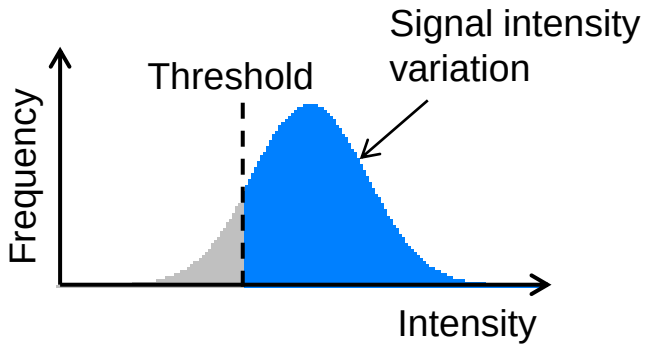
Evaluation procedure of defect sensitivity

Detection probability calculation

- Images of 100 defects on each defect size were captured 3 times with scan speed of 3 mm/s
- Signal intensity variation was obtained from pooled σ of the 100 defects
- The threshold was determined so that no false defect detection could be predicted at full-field area
- Detection probability was calculated with the signal variation and threshold

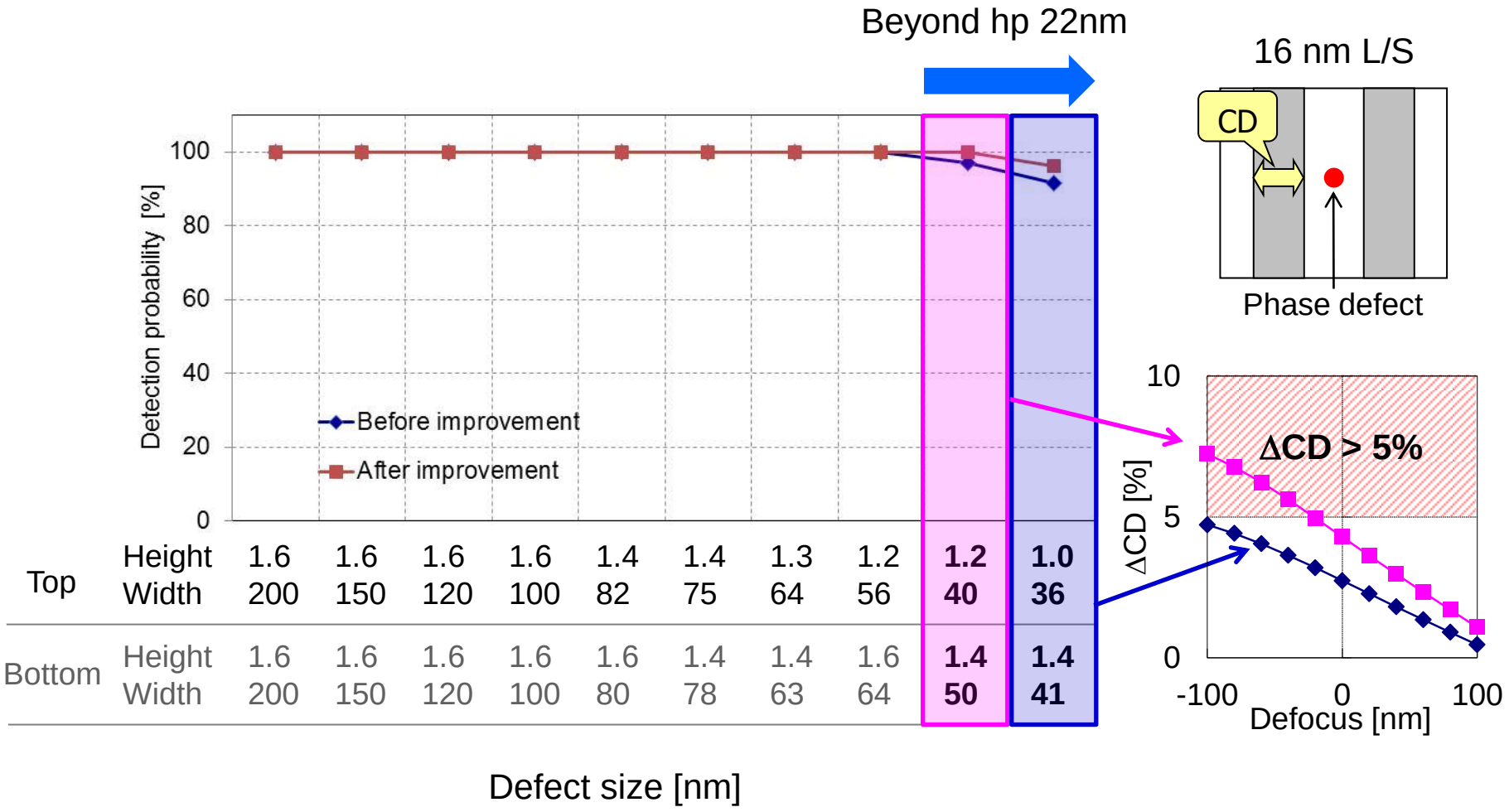


Simulation

- Impact of phase defects on hp 16 nm node was simulated

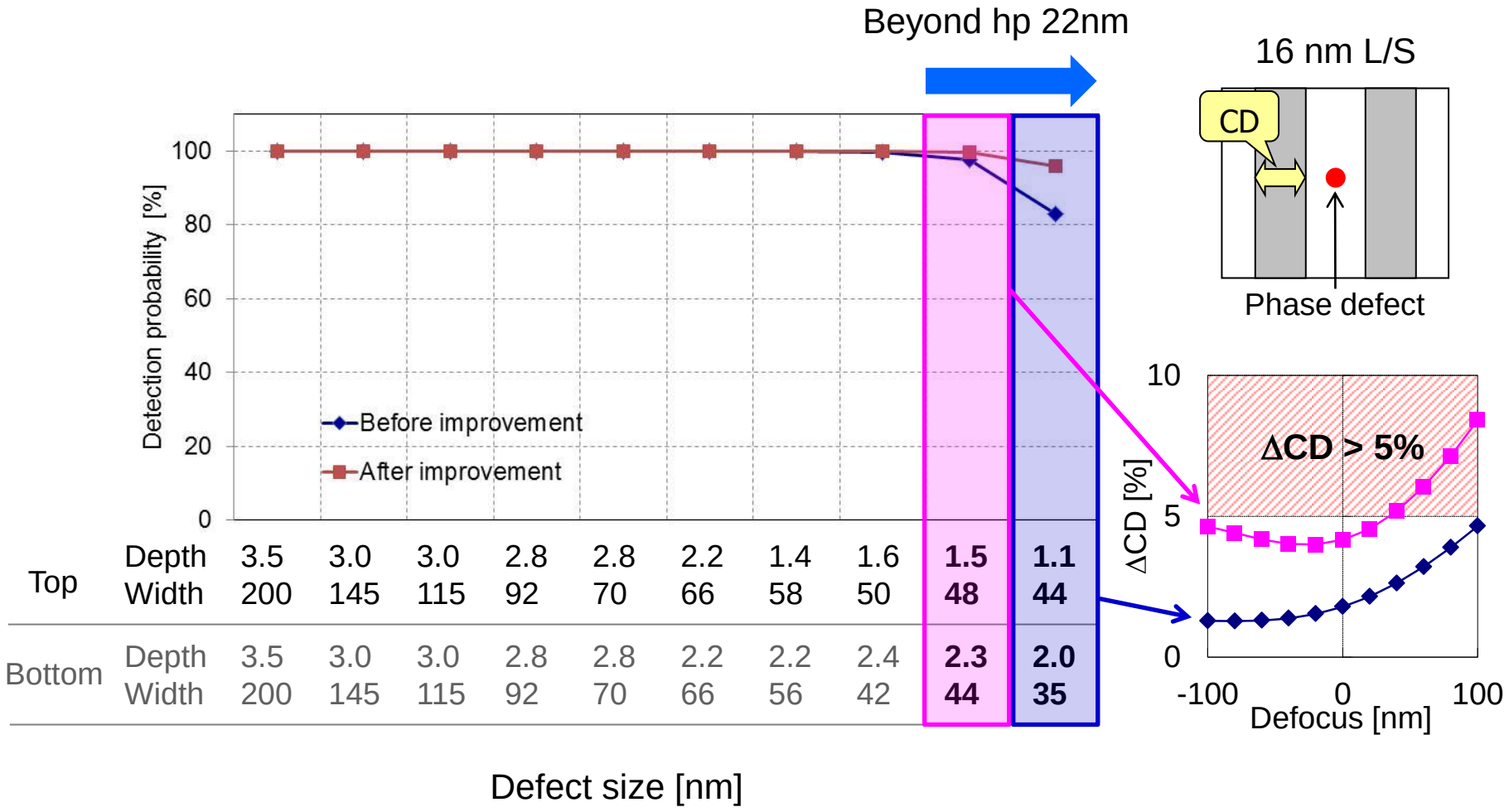
  Exposure condition: NA 0.32, σ 0.8-0.6, Dipole 90

Defect sensitivity improvement for bump



Top	Height	1.6	1.6	1.6	1.6	1.4	1.4	1.3	1.2	**1.2**	**1.0**
	Width	200	150	120	100	82	75	64	56	**40**	**36**
Bottom	Height	1.6	1.6	1.6	1.6	1.6	1.4	1.4	1.6	**1.4**	**1.4**
	Width	200	150	120	100	80	78	63	64	**50**	**41**

Defect sensitivity improvement for pit



Top	Depth	3.5	3.0	3.0	2.8	2.8	2.2	1.4	1.6	**1.5**	**1.1**
	Width	200	145	115	92	70	66	58	50	**48**	**44**
Bottom	Depth	3.5	3.0	3.0	2.8	2.8	2.2	2.2	2.4	**2.3**	**2.0**
	Width	200	145	115	92	70	66	56	42	**44**	**35**

The inspection system is predicted to be available for hp 16 nm node

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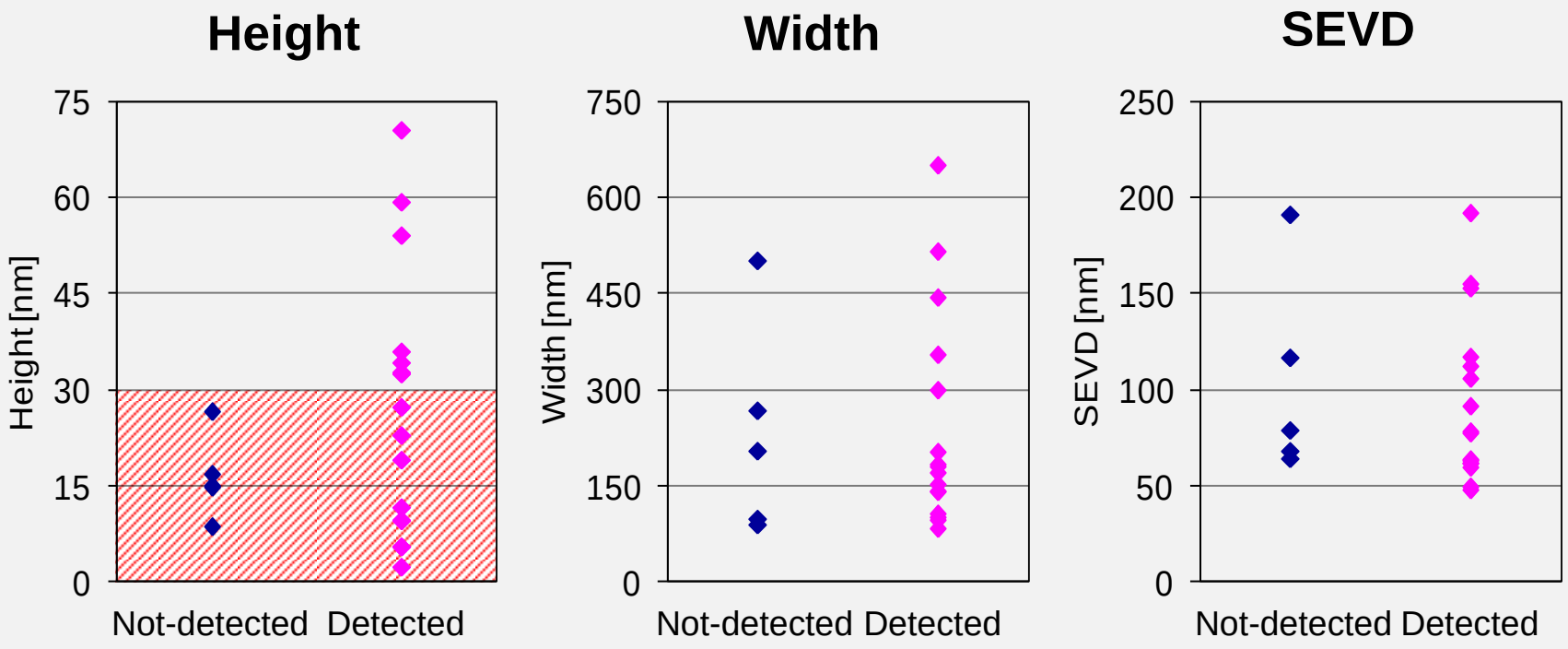
Native amplitude defects

Amplitude defect sensitivity can be less than the ones from phase defect



- ✓ Amplitude defect detection sensitivity depended on height
- ✓ Defects higher than 30 nm could be detected with high probability

T. Yamane et al., "*Phase defect analysis with actinic full-field EUVL mask blank inspection*," BACUS 2011

Programmed amplitude defects

Carbon dots formed on ML surface by EB deposition

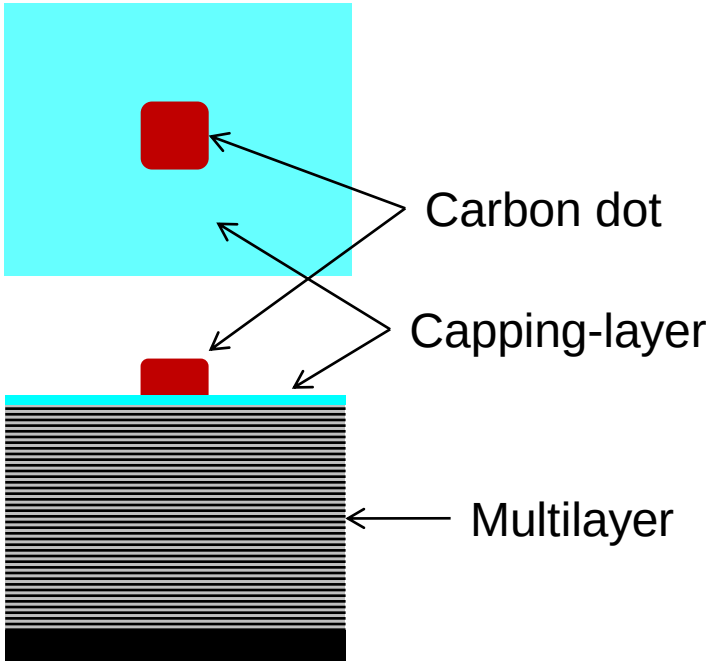
EB: 3 kV, 3076 pA

Gas: $C_{14}H_{10}$

Dose: (1) 103600 [a.u.]

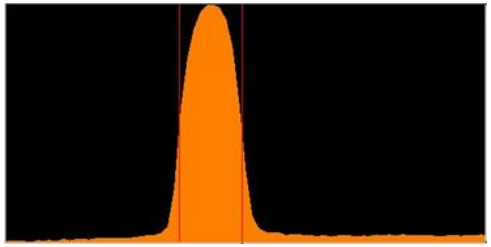
(2) 50267 [a.u.]

Width: 150 – 1000 nm



AFM measurement

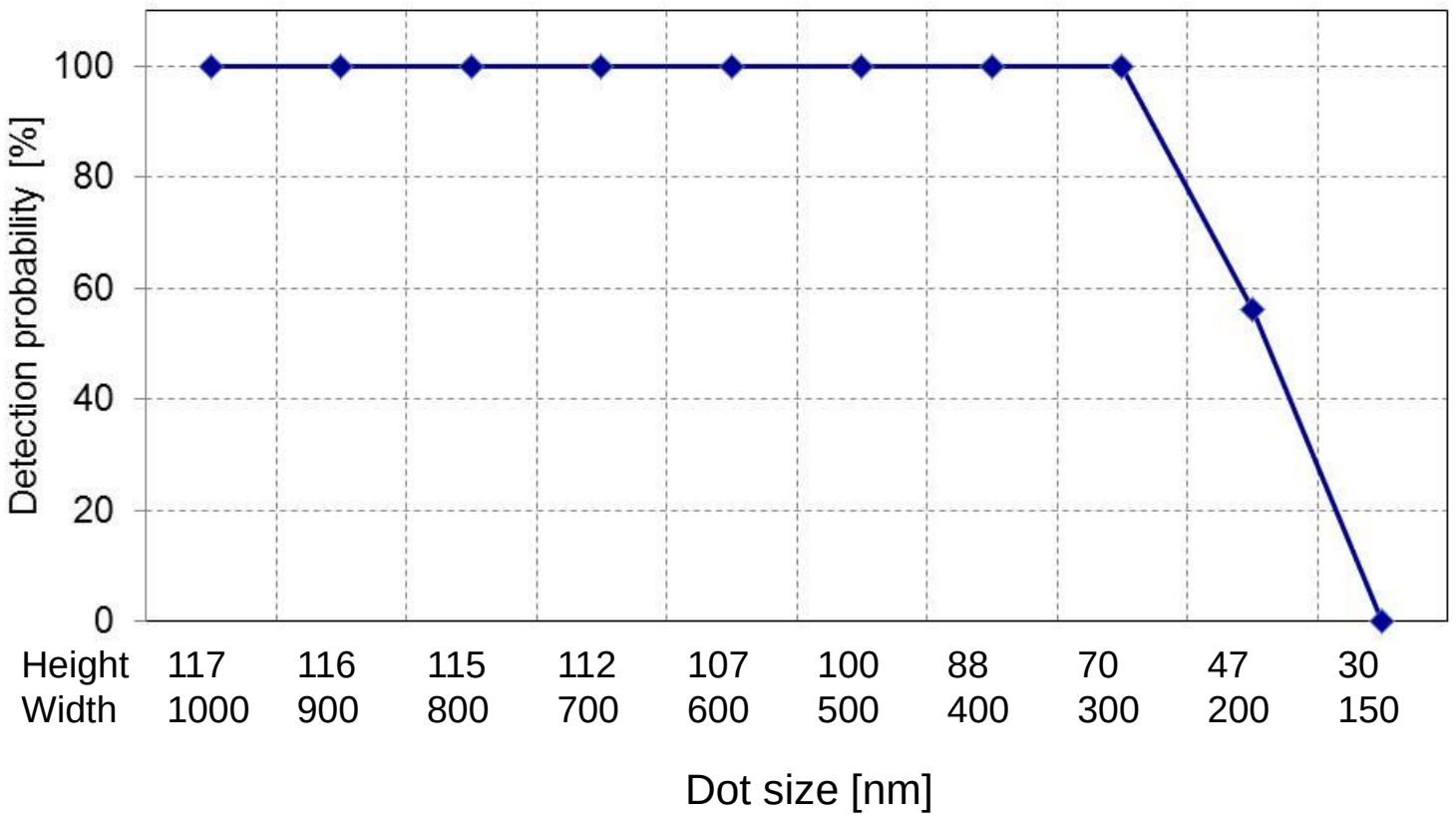
Height and width of carbon dots were measured



Detection probabilities of the carbon dots were calculated

Detection probability for carbon dots (1)

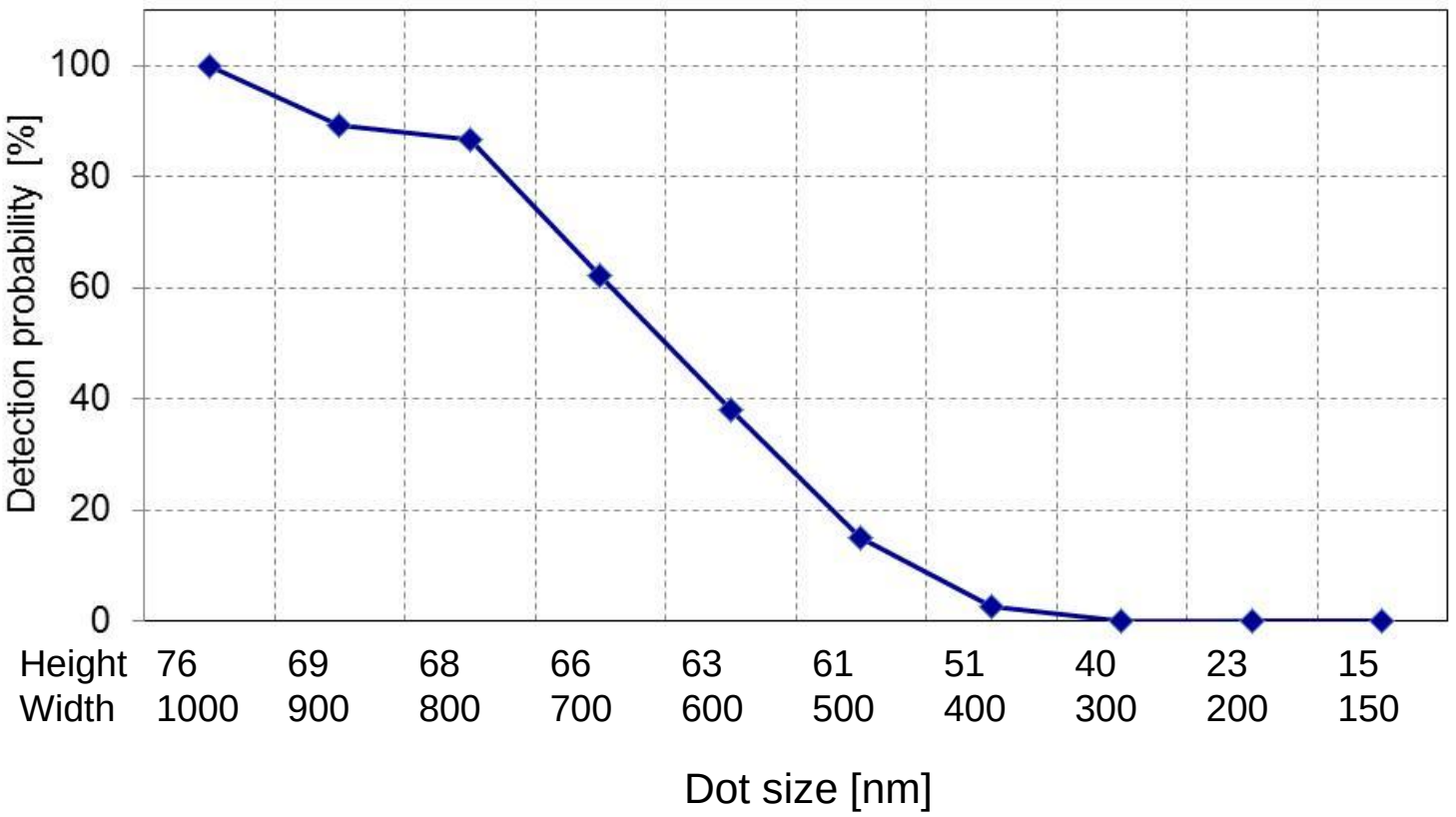
Dose condition (1)



100 % detection probability needs dot height of 70 nm

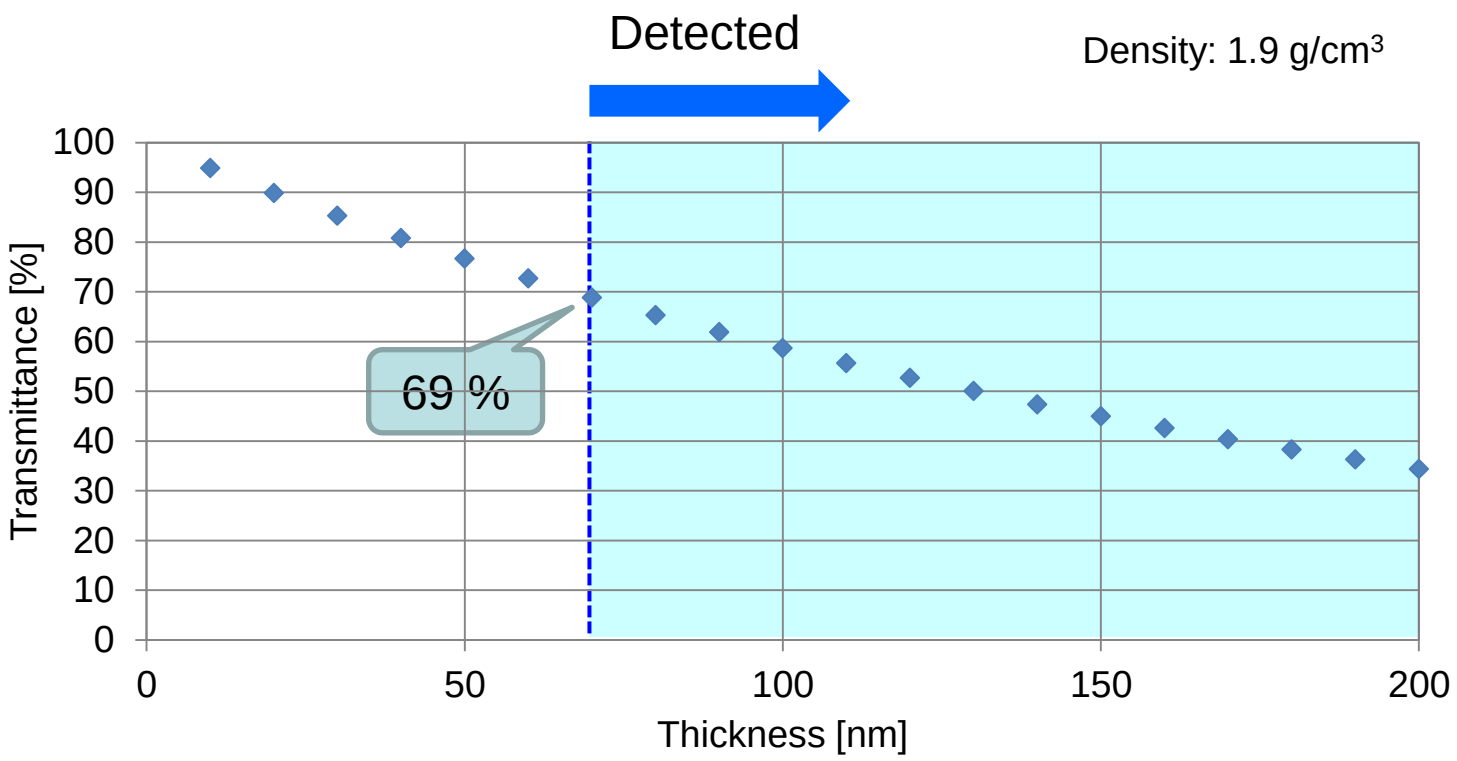
Detection probability for carbon dots (2)

Dose condition (2)



100 % detection probability needs dot height of 70 nm

Transmittance of carbon films

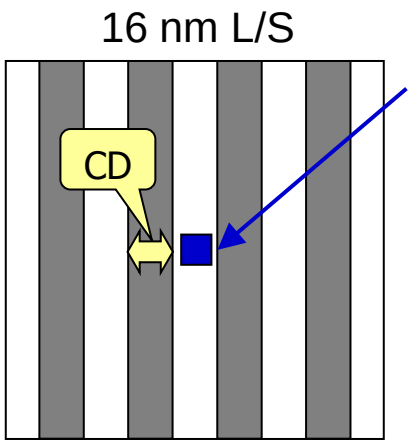


Reference: the homepage of “The center of X-ray optics, LBNL”, http://www.cxro.lbl.gov/

Amplitude defect that transmittance lower than 69 % can be detected

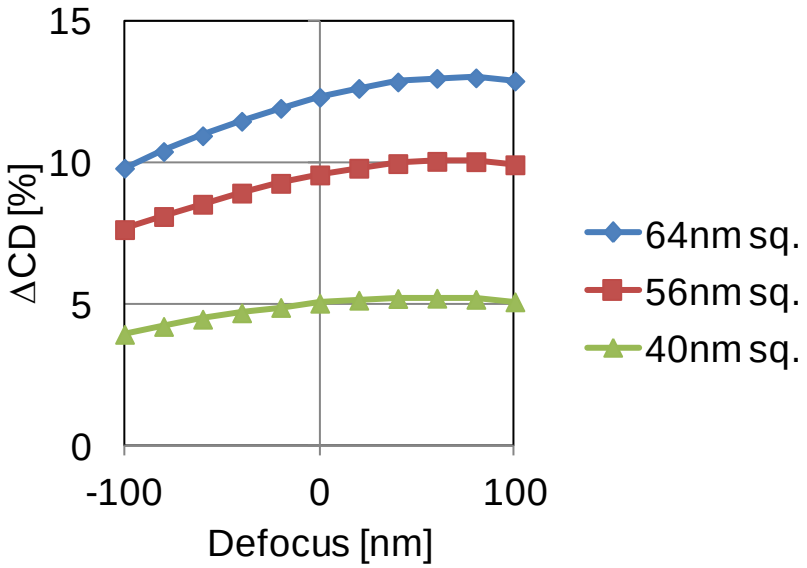
Wafer impact of 69 % transmittance defect

Impact of a 69 % transmittance defect on hp 16 nm node was simulated



Defect
Transmittance
69 %
Index of refraction
0.995

Exposure condition
NA0.32, σ0.8-0.6
Dipole 90



Amplitude defect that transmittance is higher than 69 % and area is larger than 40 nm sq. may impact on hp 16 nm node and shows less detection sensitivity

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Summary

- Auto-focusing accuracy and defect detection algorism for the actinic inspection system were improved.
- Detection probability of 1.2 nm-high 40 nm-wide phase defect was improved to nearly 100 %. The system is predicted to be available for hp 16 nm node.
- Carbon dots higher than 70 nm were detected at 100 % probability. This shows that 100 % detection for an amplitude defect needs transmittance lower than 69 %.

Acknowledgement

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