Characterization of Cross-Sectional Profile of Resist Pattern Using Grazing-Incidence Small Angle X-Ray Scattering

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◆Abstract

The scale of semiconductor devices is continuously shrinking, and the critical dimension is now expected to reach down close to ten-nanometers in the near future. The performance of such a fine device can be easily affected by a slight variation in the shape of the resist pattern. It is, therefore, important to carry out quality control over the cross-sectional profile of resists.

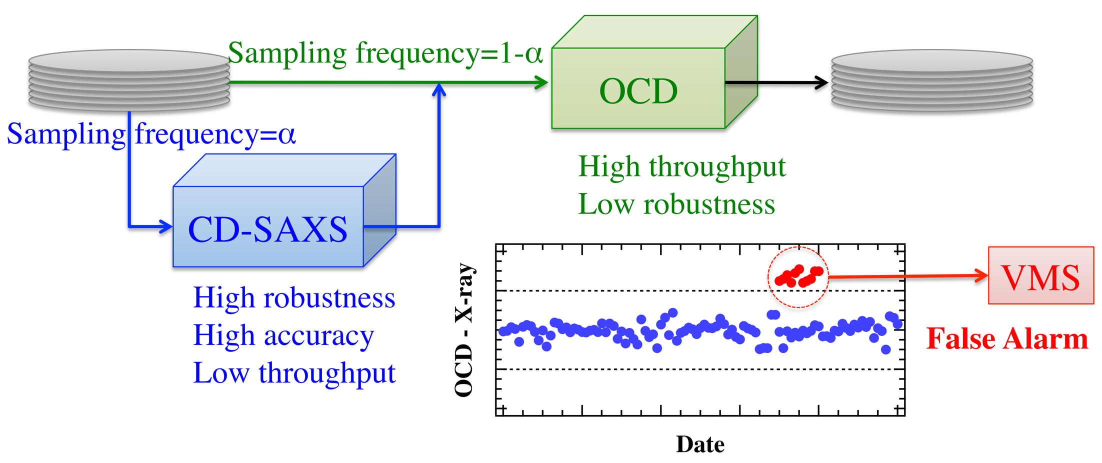
We have developed a new SAXS-based metrology tool (CD-SAXS). The system utilizes the grazing incidence geometry in order to perform quick measurements on mass production lines.

Resist line & space and hole patterns were measured by the our new x-ray metrology. The obtained cross-sectional profiles were consistent with those observed by cross-sectional SEM.

◆Current status of RIGAKU CD-SAXS

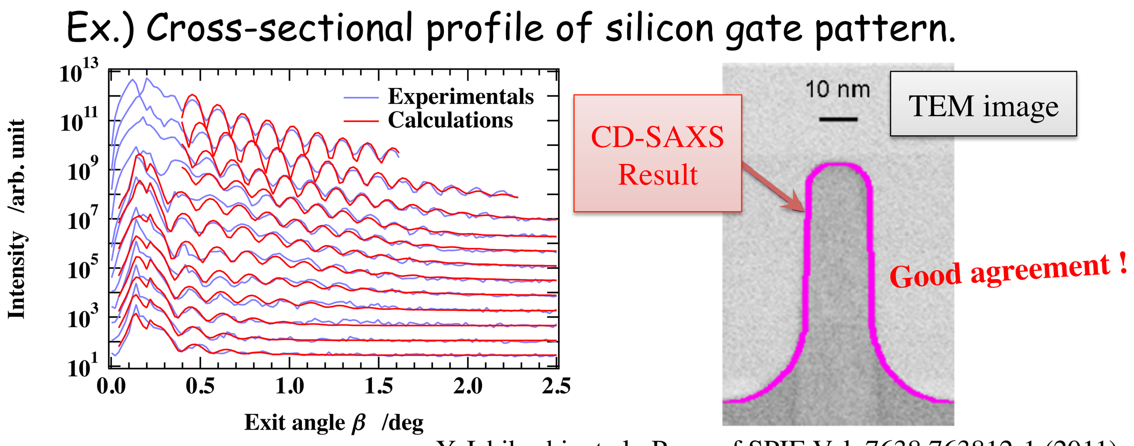
CD-SAXS measures only signal from periodic structure, such as line & space, dot and hole. The signal cannot be affected by the under-layer structure. OCD metrology is low robustness for a slight variation of optical parameters of under-layer structure.

Recently, verification metrology system (VMS) has been proposed and introduced on mass production lines.



H. Abe, et al., Proc. of SPIE Vol. 9050 90501L-2 (2014)

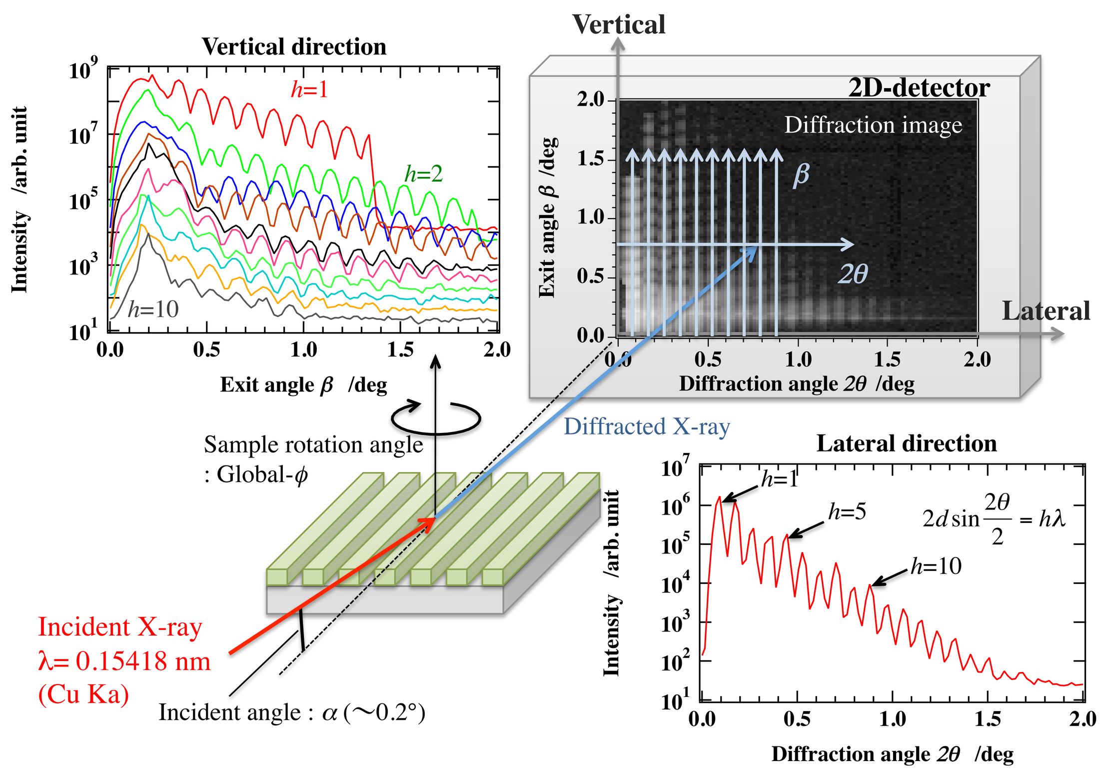
Ex.) Cross-sectional profile of silicon gate pattern.



Y. Ishibashi, et al., Proc. of SPIE Vol. 7638 763812-1 (2011)

◆Grazing incidence small-angle x-ray scattering

- Monochromatic x-ray irradiates to the sample surface.
- The incident angle is set to be very close to the critical angle of total external reflection.
- The sample has to be rotated around the vertical axis at the irradiated point during the measurement.
- Diffracted x-rays are collected by a two dimensional pixel array detector.



◆ Lateral direction

- Average pitch can be analyzed by the diffraction angle.
- Line-width, line-width variation (LWR-like) and pitch variation (LER-like) can be determined by the intensity ratio of these diffraction peaks.

◆ Vertical direction

- Each diffraction peaks has a characteristic fringe pattern in the vertical direction.
- Depth, sidewall shape, and corner rounding shape can be determined by the periodicity and the phase of the fringe patterns, which strongly depend on the order of diffraction ***h***.

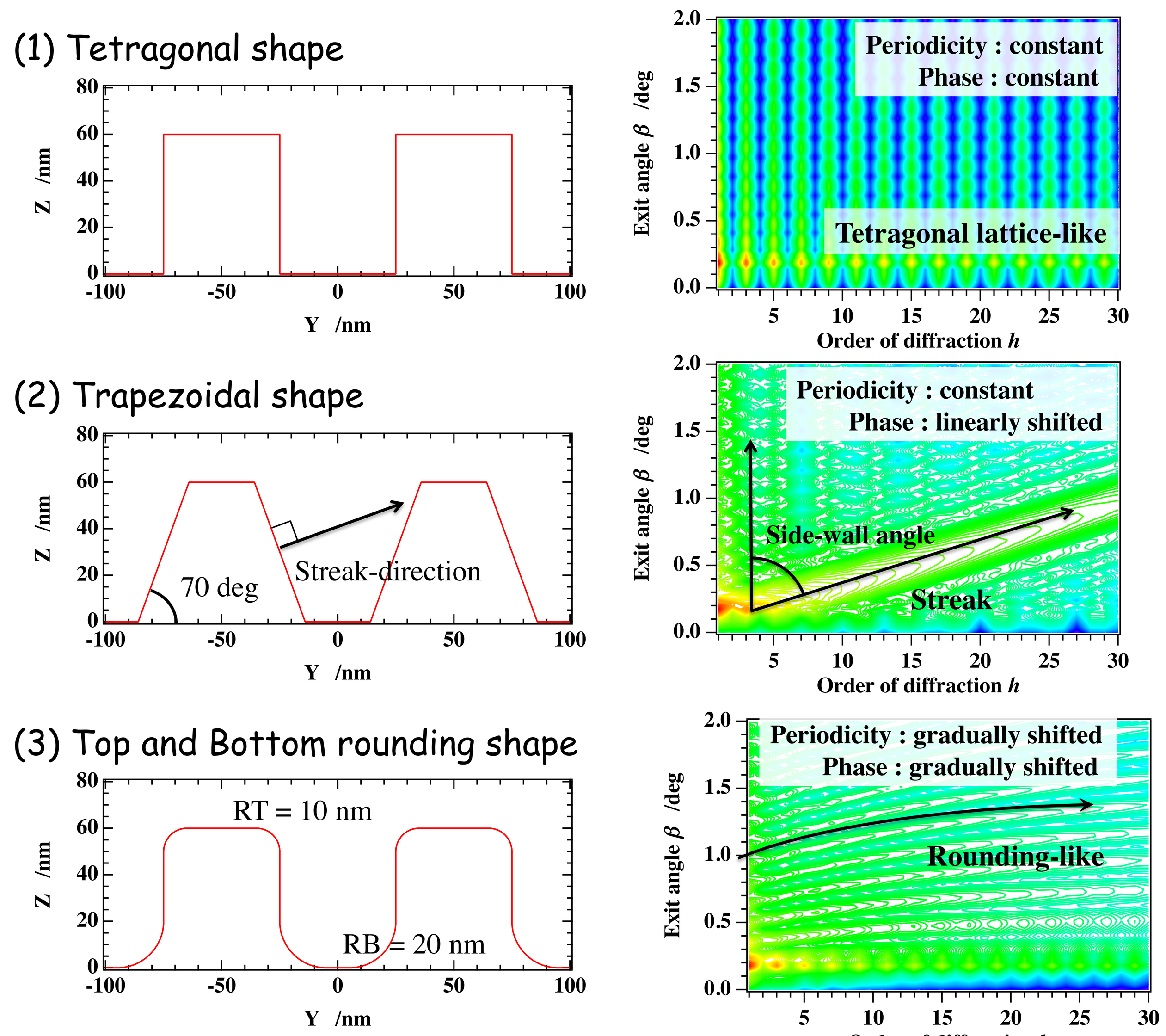
Item	Specification
X-ray source	Micro-focus x-ray tube (30W), Multilayer mirror optics Beam size : 15 μm vertical × 2 mm horizontal
Detector	PILATUS 100K (0.172 mm/pixel)

◆Sensitivity of diffraction pattern for the variation of cross-sectional profile

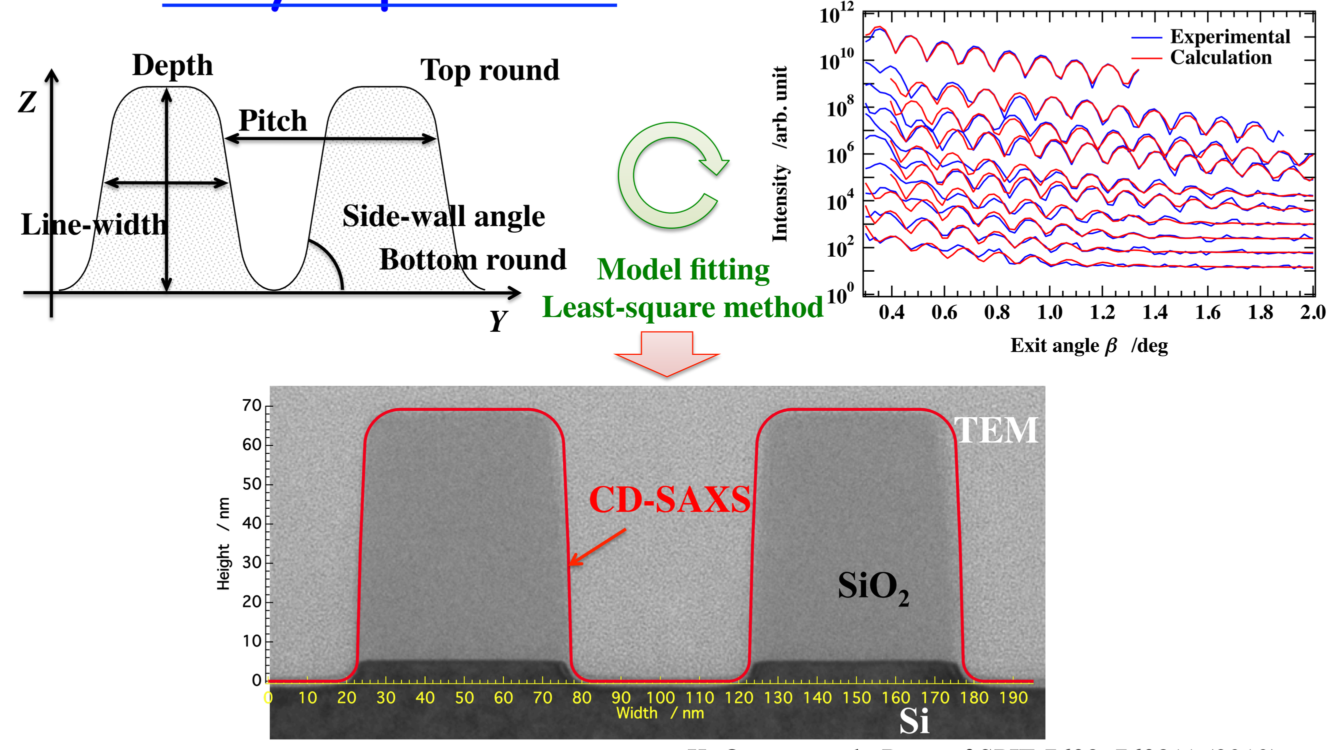
(1) Tetragonal shape

(2) Trapezoidal shape

(3) Top and Bottom rounding shape



◆Analysis procedure



K. Omote, et al., Proc. of SPIE 7638, 763811 (2010)

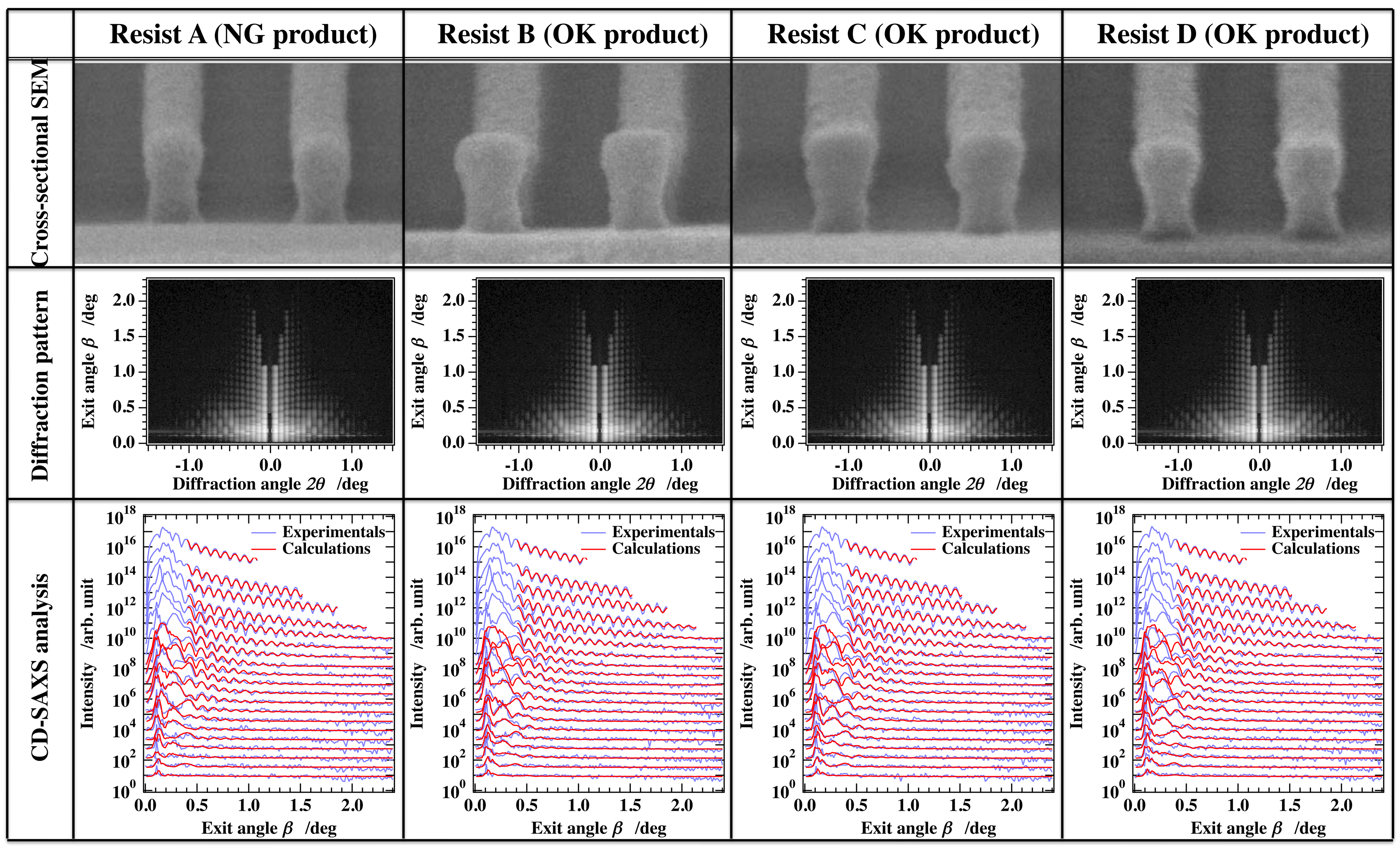
◆Cross-sectional profile analysis of resist line & space pattern

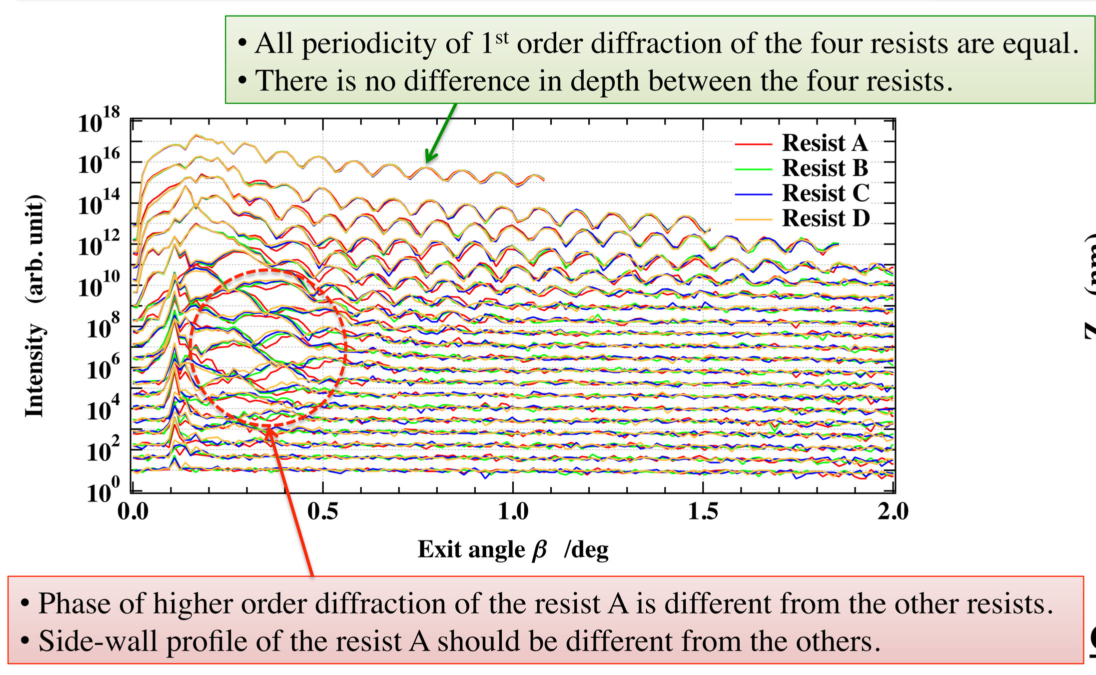
◆ Sample preparation

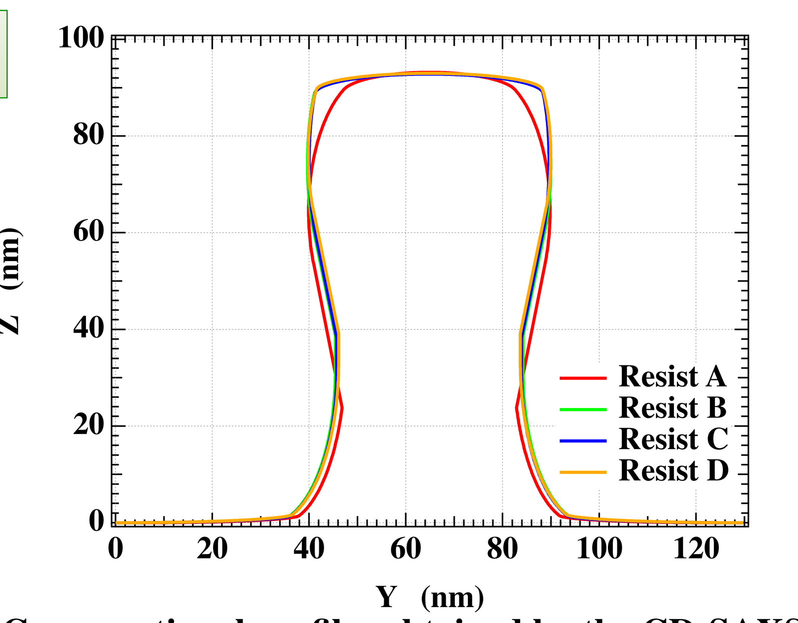
- Four kinds of resist L/S pattern wafers with pitch size of 130 nm were fabricated with different material composition and exposure condition, intentionally, in order to obtain different cross-sectional profile between four resists.
- Resist A is NG product. Resist B, C, and D are OK products.

◆ Motivation

- **<u>Our challenge is to distinguish the OK products and NG products.</u>**







<u>Cross-sectional profiles obtained by the CD-SAXS</u>

◆ Results

- Obtained cross-sectional profiles show an inversed tapered shape in the four resists.
- Top corner rounding shape of the resist A (NG product) is different from the others (OK products).
- These results can be regarded as consistent with the cross-sectional SEM results.
- Our new x-ray metrology, it is possible to distinguish the OK product and NG product.

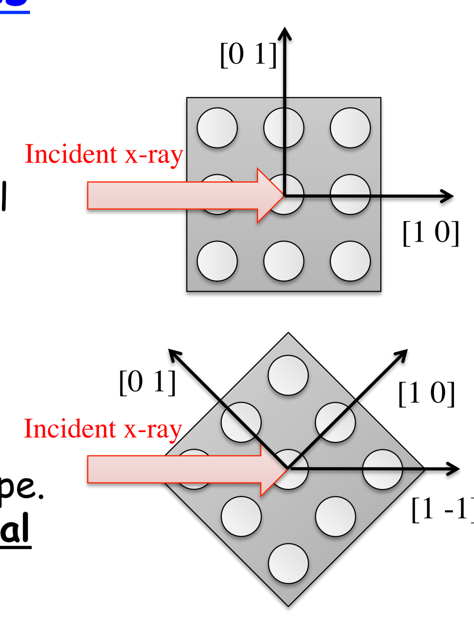
◆Cross-sectional profile analysis of resist contact holes

◆ Sample preparation

- Two kinds of resist hole-patterned wafers were fabricated using different composition and exposure condition.
- The holes are arranged in a 2D square lattice-like form in the lateral plane with the pitch size of 90 nm.

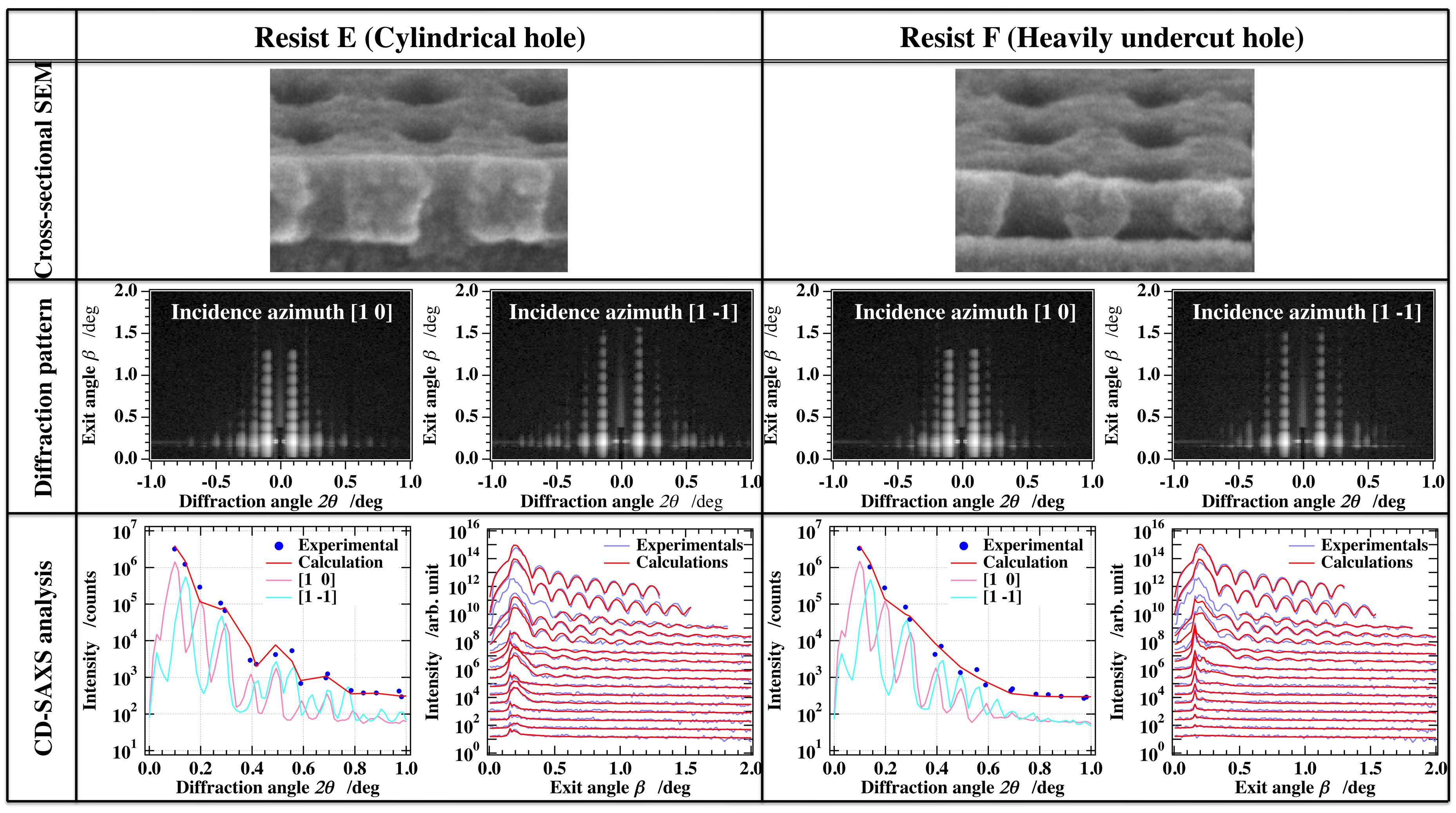
◆ Experimental method

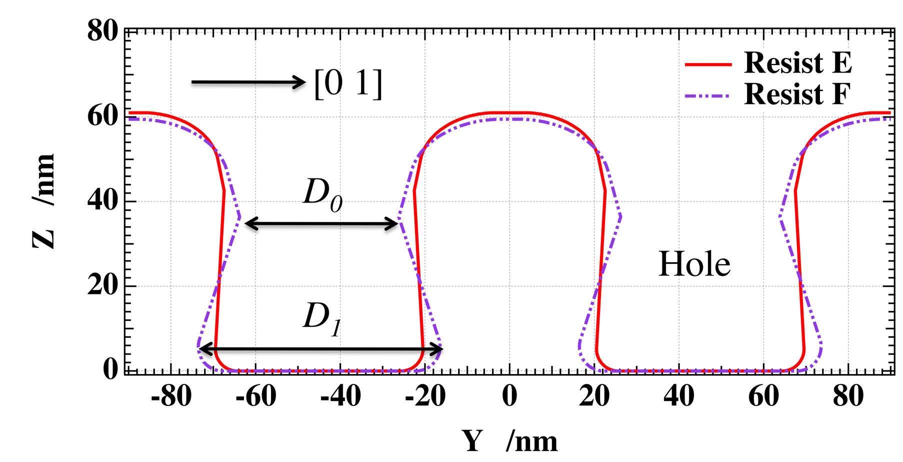
- Diffraction data were collected in two directions [1 0] and [1 -1].



◆Motivation

- CD-SEM employing top view observation cannot detect undercut shape.
- **<u>Our challenge is to detect a slight variation of the cross-sectional profile between the two resists.</u>**





<u>Cross-sectional profiles obtained by the CD-SAXS</u>

	Diameter (nm)		Depth (nm)	Side-wall angle (deg)	
	D_0	D_1		Top	Bottom
Resist E	44.9	49.0	61.0	78.6	93.2
Resist F	37.6	57.1	59.5	74.5	108.2

	Corner radius (nm)		Pitch variation (nm)	Diameter variation (nm)	Depth variation (nm)
	Top	Bottom			
Resist E	13.0	5.2	3.3	1.1	0.4
Resist F	14.9	5.8	4.1	>3	0.5

◆ Results

- The CD-SAXS results reproduced the characteristics obtained by the cross-sectional SEM.
- The resist E has the rather vertical cylindrical shape.
- The resist F has the heavily undercut shape.
- Our new x-ray metrology, it is possible to detect a slight variation of cross-sectional profile of resist hole pattern.

◆Conclusion

Our newly-developed x-ray metrology tool, CD-SAXS, has been demonstrated. Cross-sectional profiles of resist patterns were measured by the instrument. The results obtained by the CD-SAXS were consistent with those obtained by cross-sectional SEM observation. CD-SAXS has a capability for measuring cross-sectional profile non- destructively. Our new x-ray method is very effective in CD metrology on mass production lines.

◆Acknowledgement

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