OP-P12

Effects of aberration and flare on the lithographic performance of SFET

○Yuusuke Tanaka, Kazuo Tawarayama,
Shunko Magoshi, and Hiroyuki Tanaka

MIRAI-Semiconductor Leading Edge Technologies Inc. (Selete)

E-mail: tanaka.yuusuke@selete.co.jp

Outline

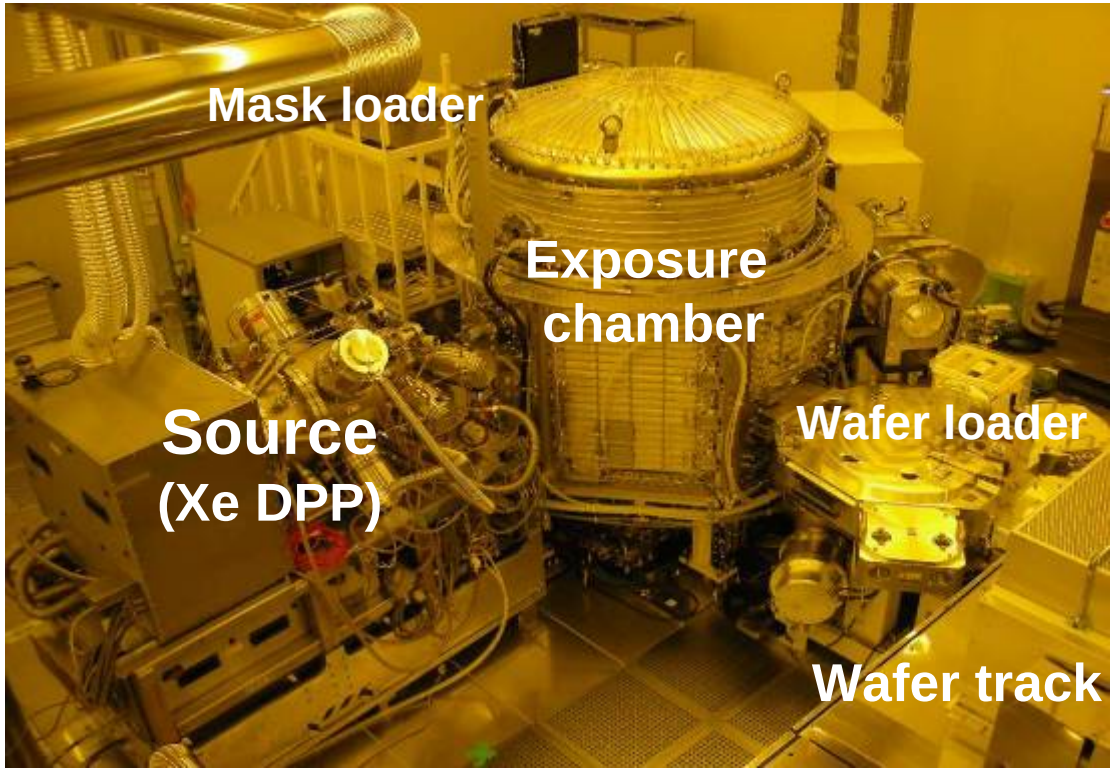
1. Specifications of Small Field Exposure Tool (SFET)
2. Effect of aberration on L/S patterns
3. Effect of aberration on C/H patterns
4. Effect of flare on L/S patterns
5. Resolution enhancement by slit illumination
6. Conclusions

Specifications of Small Field Exposure Tool

Purposes

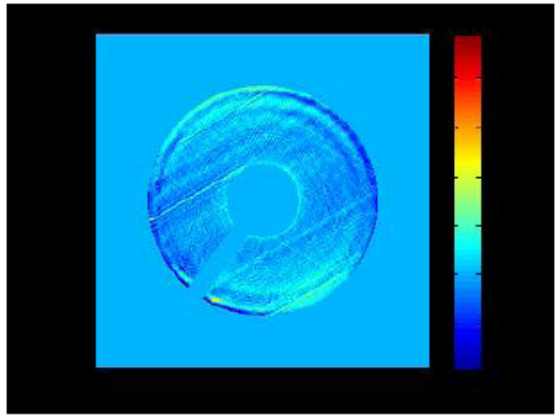
- Optimize mask structure
- Develop resist materials
- Evaluate optics & source lifetime

Items	Target Specifications
NA	0.3
Field size	0.2 x 0.6 mm
Magnification	1/5
Wavefront error	＜0.9 nm rms
Flare	＜7%（MSFR）
Resolution	32 nm L/S
Source power	0.5W @IF
Wafer size	300 mm



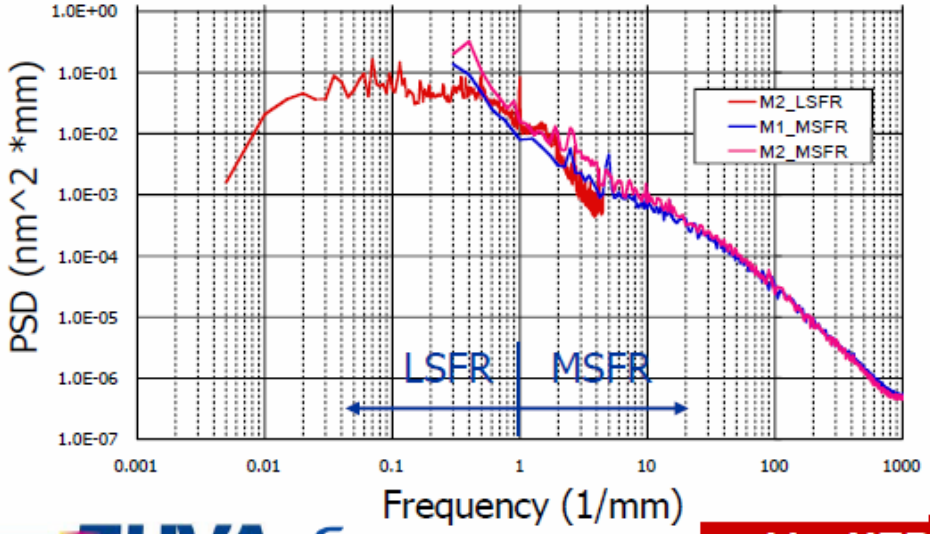
Aberration and Flare of SFET Optics

Wavefront aberration and Flare



Wavefront AZ5-37	Residual (1/CA - 1/mm)	Total
0.51	0.49	0.71

(nm RMS)



	LSFR	MSFR
Measurement (nmRMS)	0.265	0.391
Flare (%)	6.08	6.64

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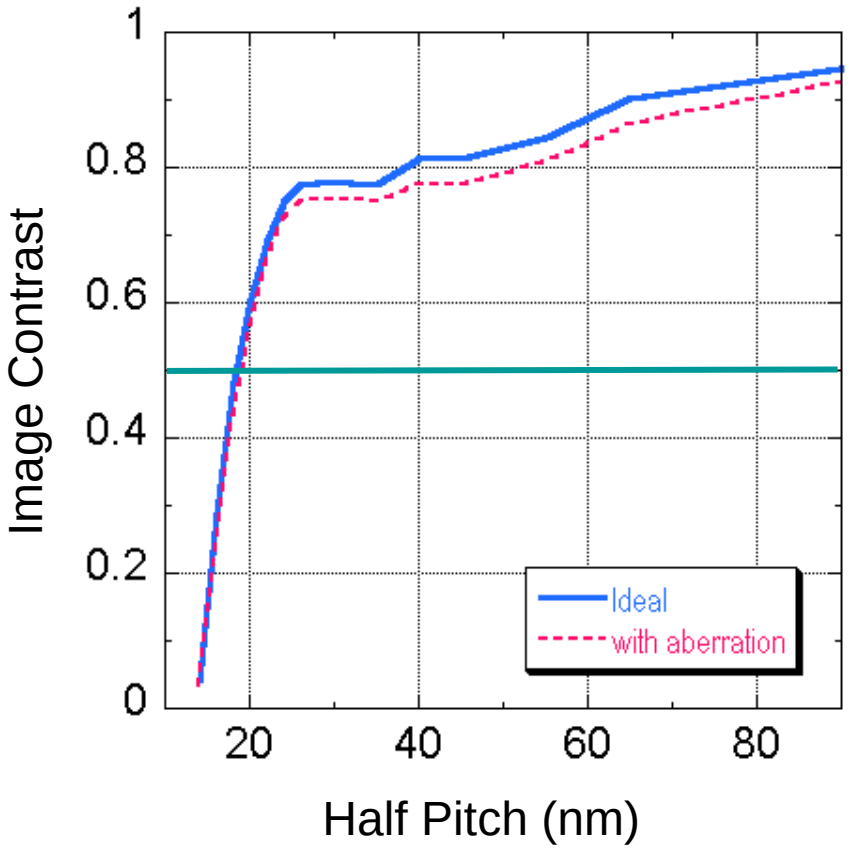
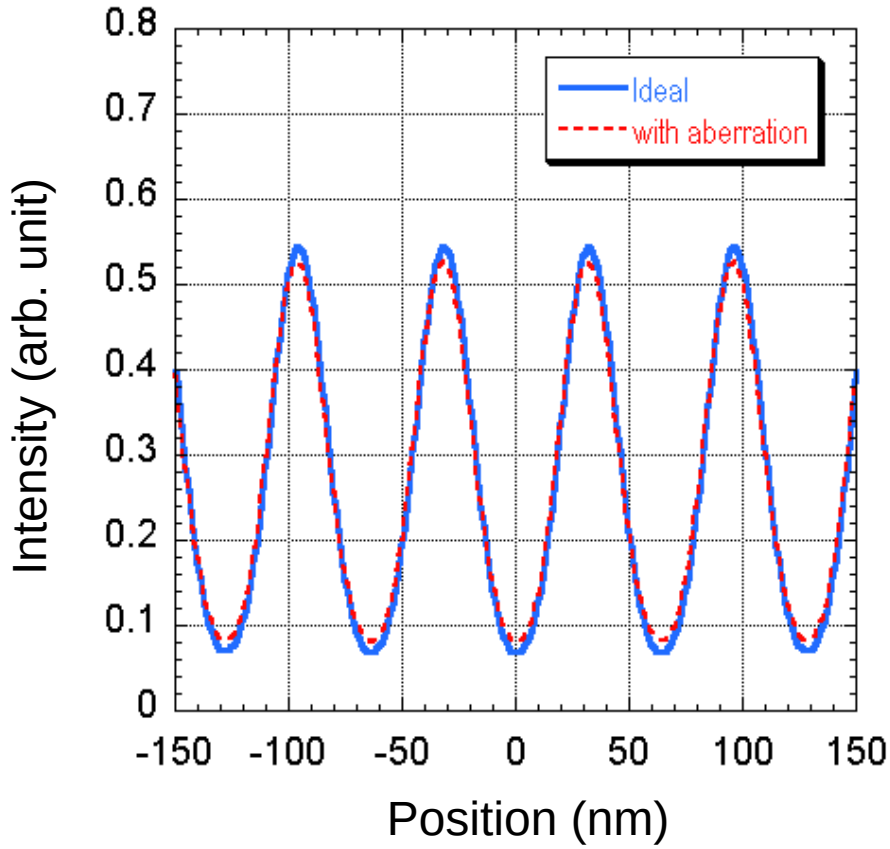
Effect of Aberration on Image Contrast (L/S)



(1) Image Contrast of L/S patterns

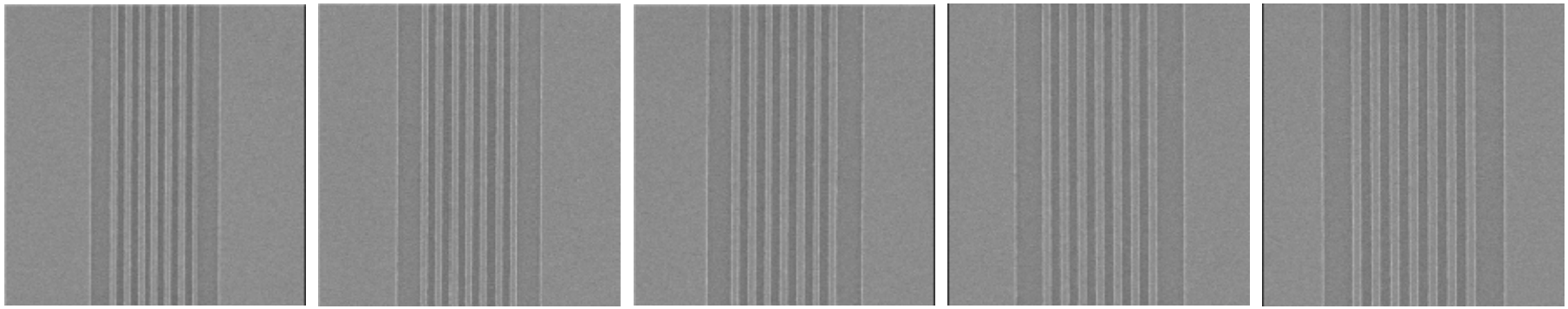


(2) Aerial Image of 32 nm L/S

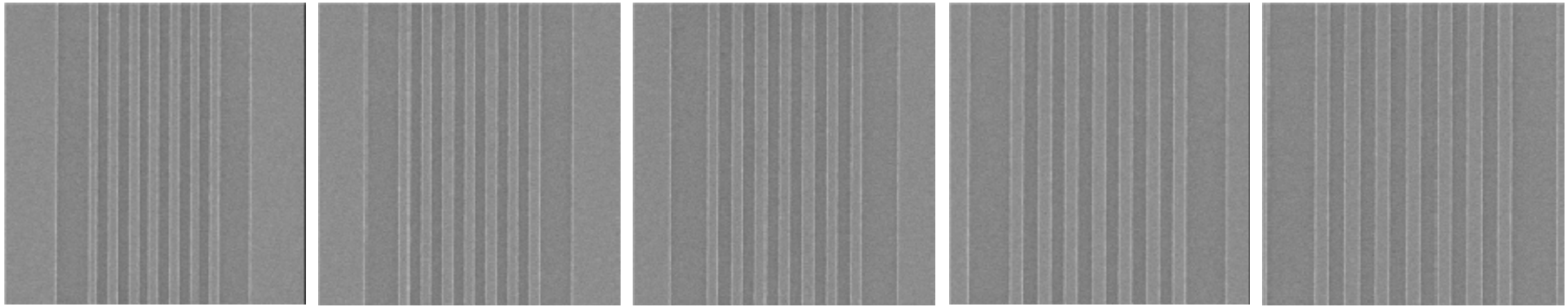
<Simulation conditions> Aberration: 0.76 nm RMS (AZ37) Flare: 0%
Illumination : Annular (σ=0.3/0.7) Mask structure: 2D

Effect of aberration on image contrast might be small for L/S patterns.

Mask Pattern Shapes of L/S Patterns



100 nm L/S | 110 nm L/S | 120 nm L/S | 130 nm L/S | 140 nm L/S

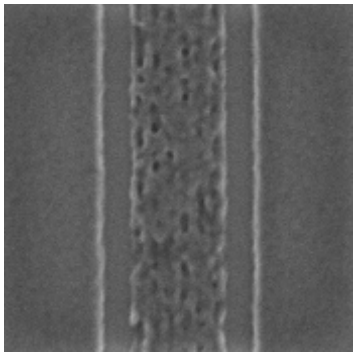


150 nm L/S | 160 nm L/S | 175 nm L/S | 200 nm L/S | 225 nm L/S

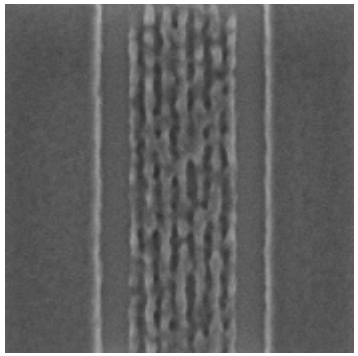
Mask structure: LR-TaBN(70nm)/CrN(10nm)/ML(40pairs)/Quarz

Mask patterns were successfully fabricated down to 100 nm L/S patterns.

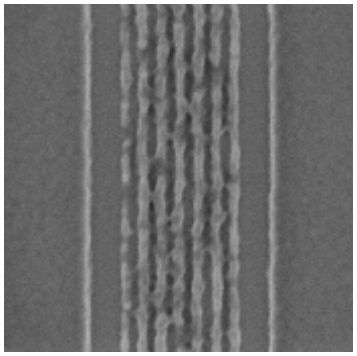
Resolution of L/S Patterns (Annular)



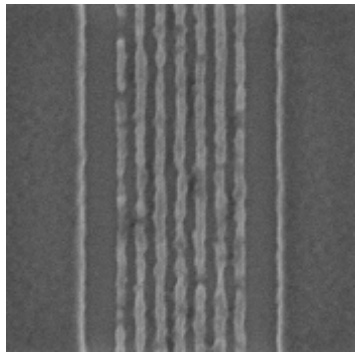
20 nm L/S



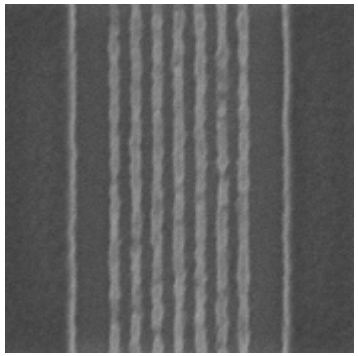
22 nm L/S



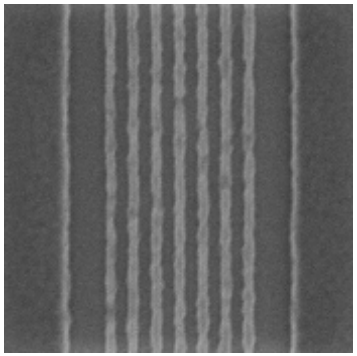
24 nm L/S



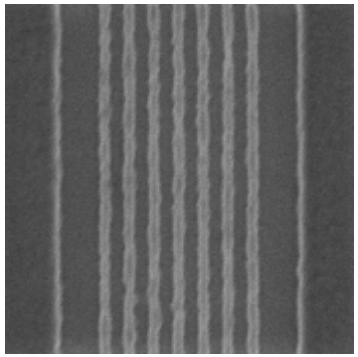
26 nm L/S



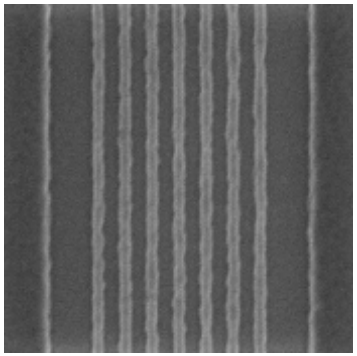
28 nm L/S



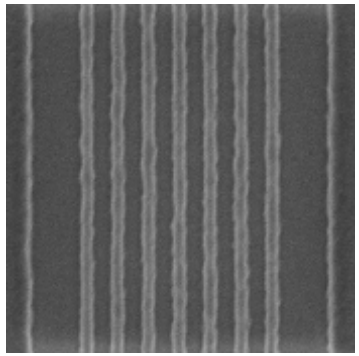
30 nm L/S



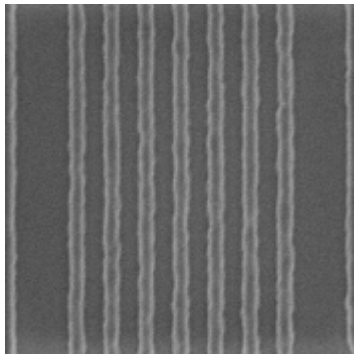
32 nm L/S



35 nm L/S

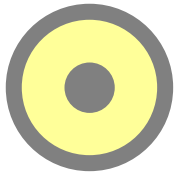


40 nm L/S



45 nm L/S

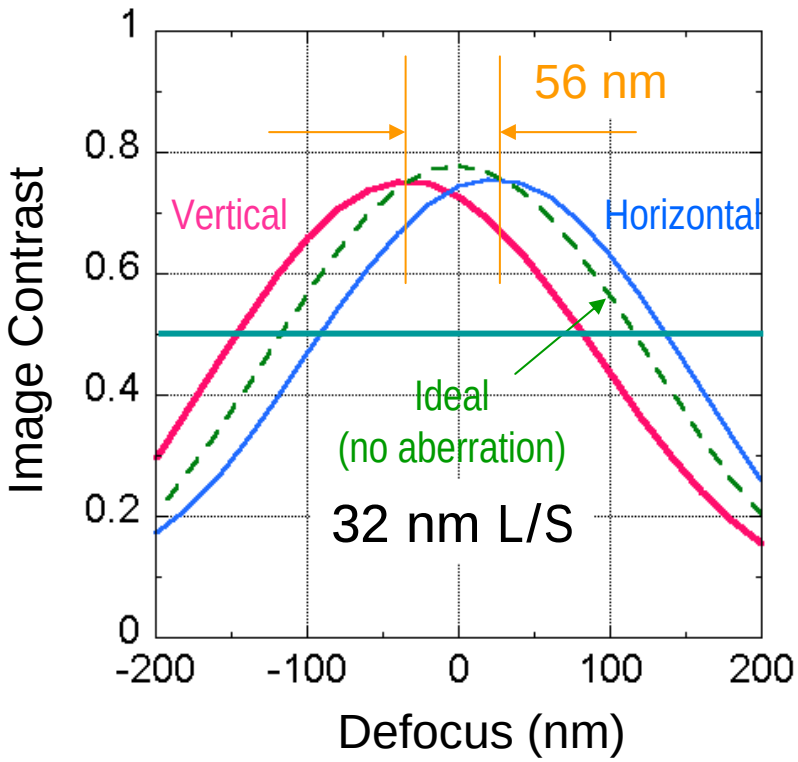
Resist: SSR2 (60 nm^{t})

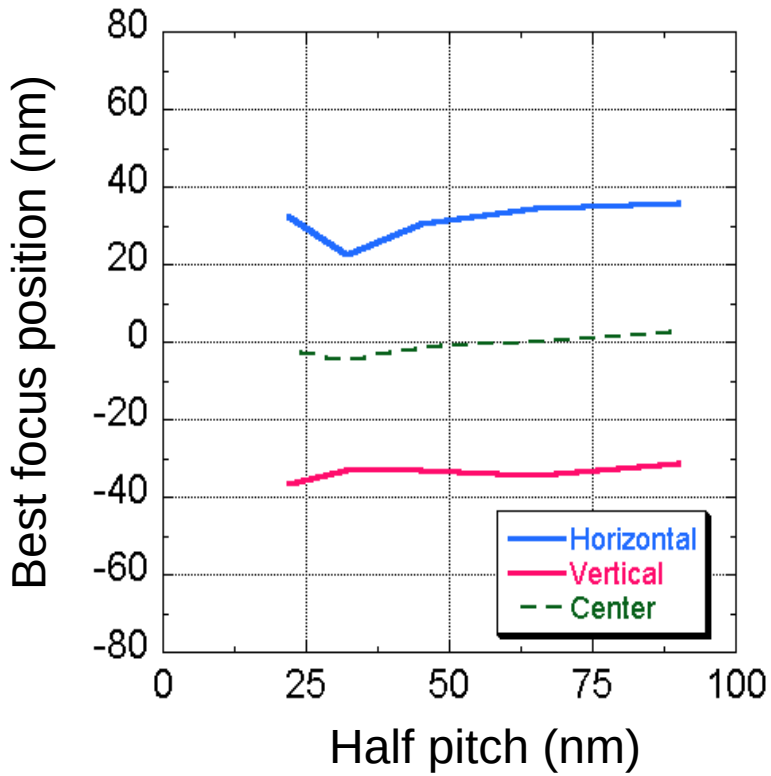


Annular
(σ=0.3/0.7)

26 nm L/S patterns were almost resolved under annular illumination.
Resolution might be limited by resist characteristics.

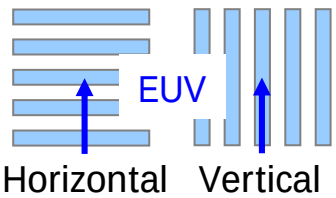
Effect of Aberration on Focus Shift (L/S)





(1) Focus shift between horizontal and vertical L/S

(2) Focus shift as a function of half pitch

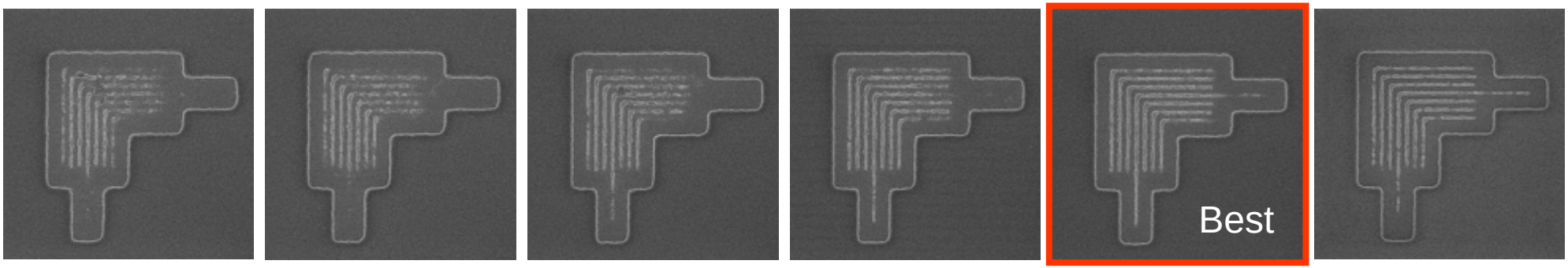


<Simulation conditions> Aberration: 0.76 nm RMS Flare: 0%
Illumination : Annular (σ=0.3/0.7) Mask structure: 2D

Calculated focus shift between horizontal and vertical L/S was about 60 nm.
Calculated focus shift among various sizes of L/S was less than 20 nm.

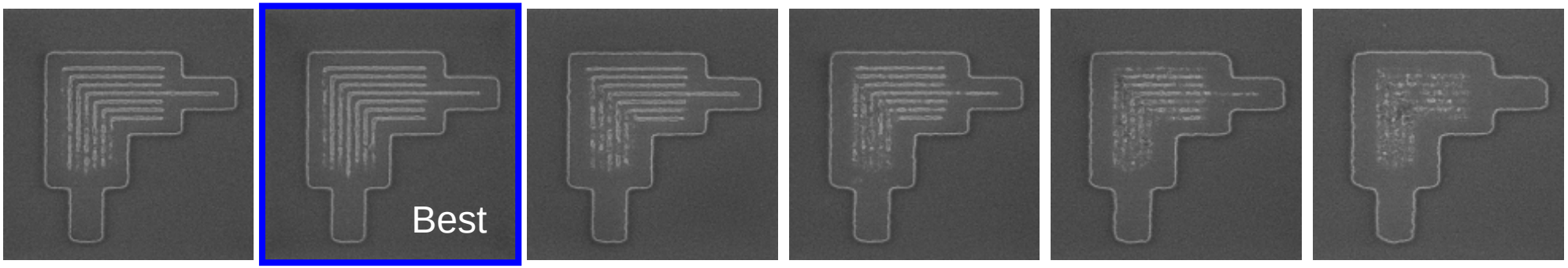
Defocus Characteristics of 32 nm L/S Patterns

V-line



-80 nm | -60 nm | -40 nm | -20 nm | ±0 nm | +20 nm

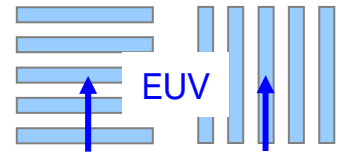
H-line



+40 nm | +60 nm | +80 nm | +100 nm | +120 nm | +140 nm

Defocus

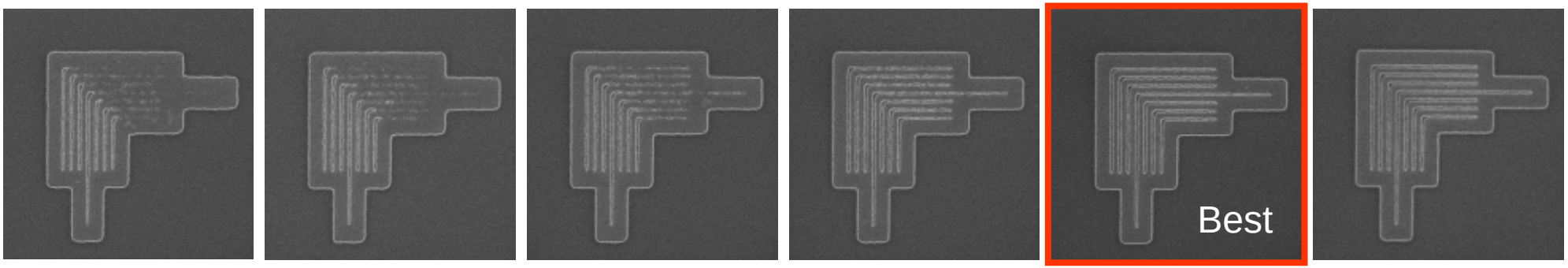
Resist: SSR2 (60 nm^t)



Focus shift between horizontal and vertical L/S was almost equal to the simulation result.

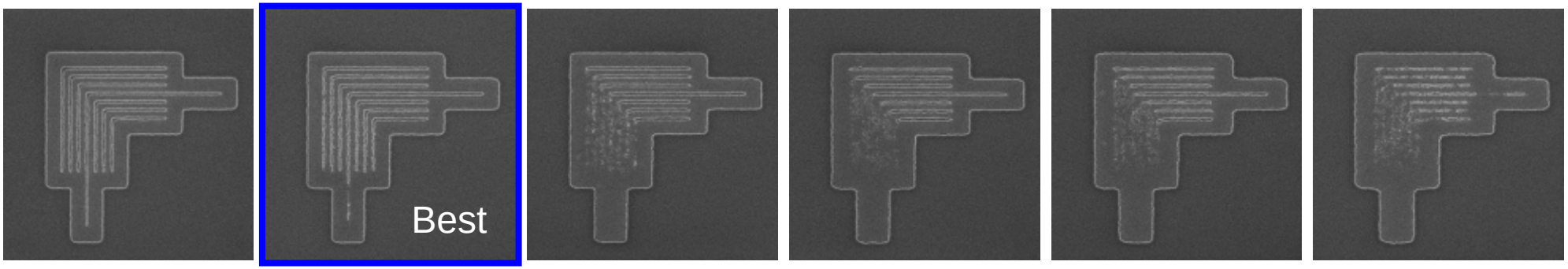
Defocus Characteristics of 45 nm L/S Patterns

V-line



-80 nm | -60 nm | -40 nm | -20 nm | ±0 nm | +20 nm

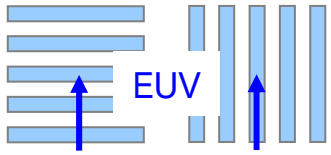
H-line



+40 nm | +60 nm | +80 nm | +100 nm | +120 nm | +140 nm

Defocus

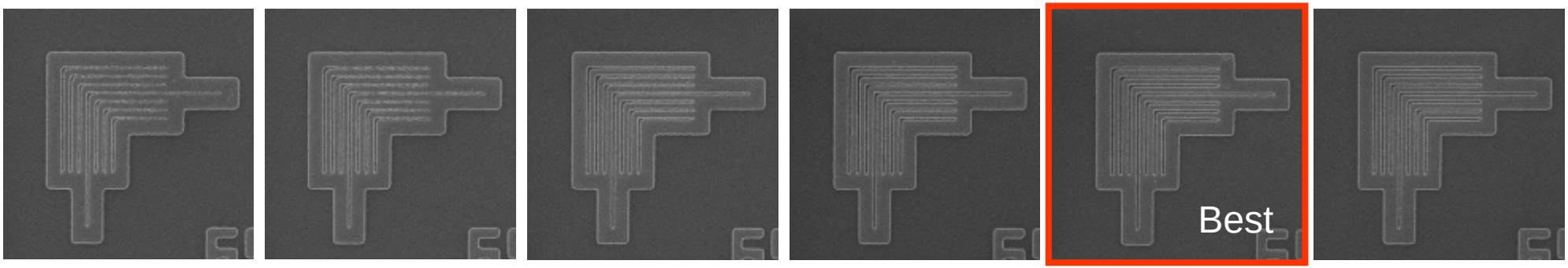
Resist: SSR2 (60 nm^t)



Best focus positions of 45 nm L/S were almost equal to those of 32 nm L/S.

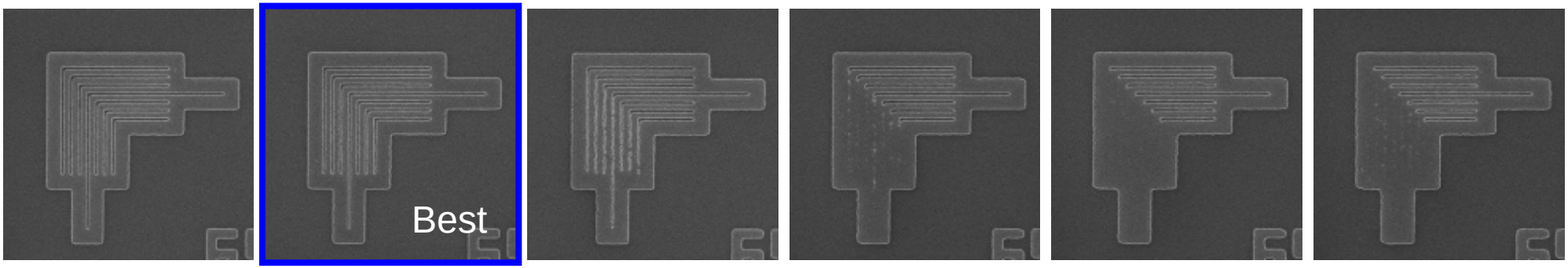
Defocus Characteristics of 65 nm L/S Patterns

V-line



-80 nm | -60 nm | -40 nm | -20 nm | ±0 nm | +20 nm

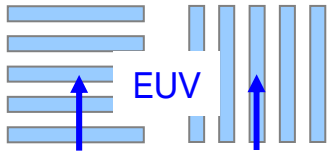
H-line



+40 nm | +60 nm | +80 nm | +100 nm | +120 nm | +140 nm

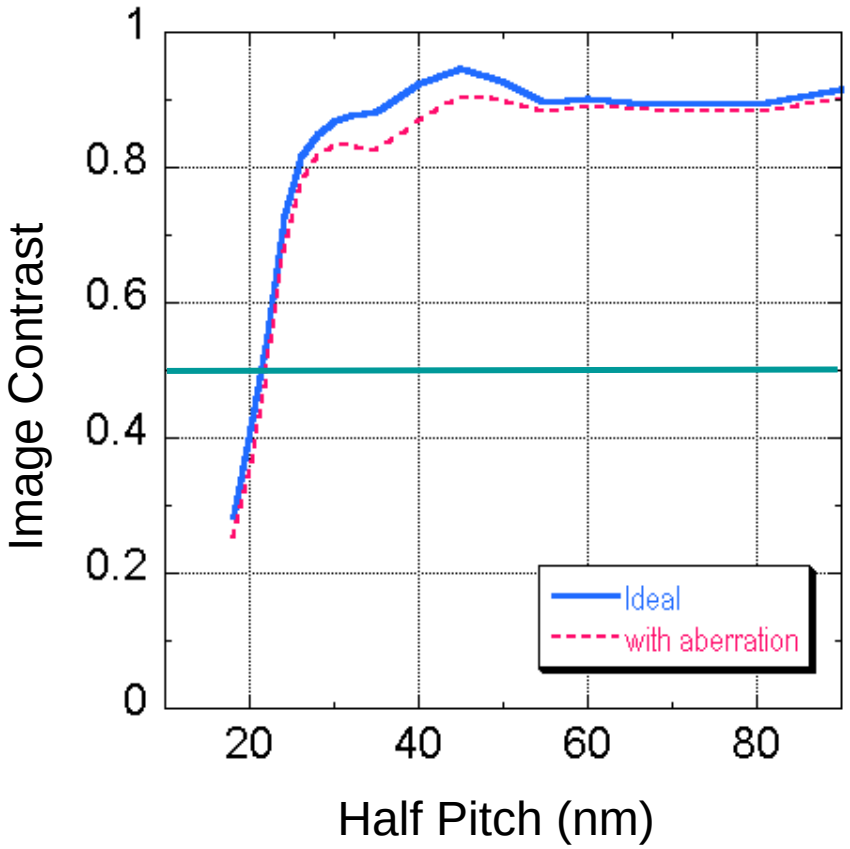
Defocus

Resist: SSR2 (60 nm^t)

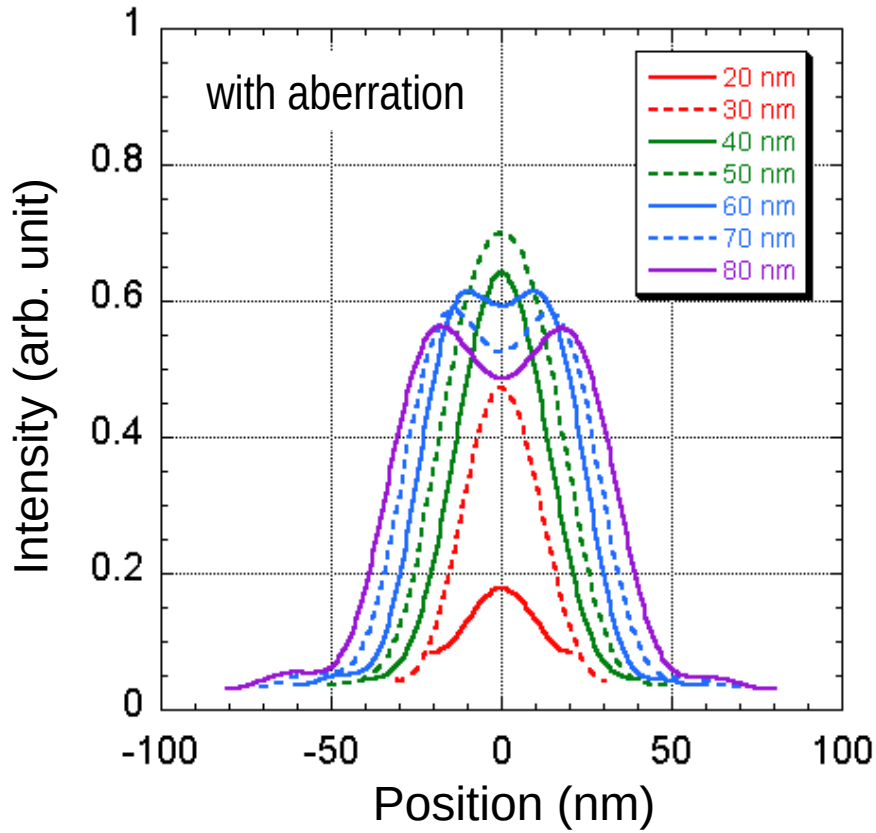


Best focus positions of 65 nm L/S were almost equal to those of 32 nm L/S.

Effect of Aberration on Image Contrast (C/H)



(1) Image Contrast of Dense C/H

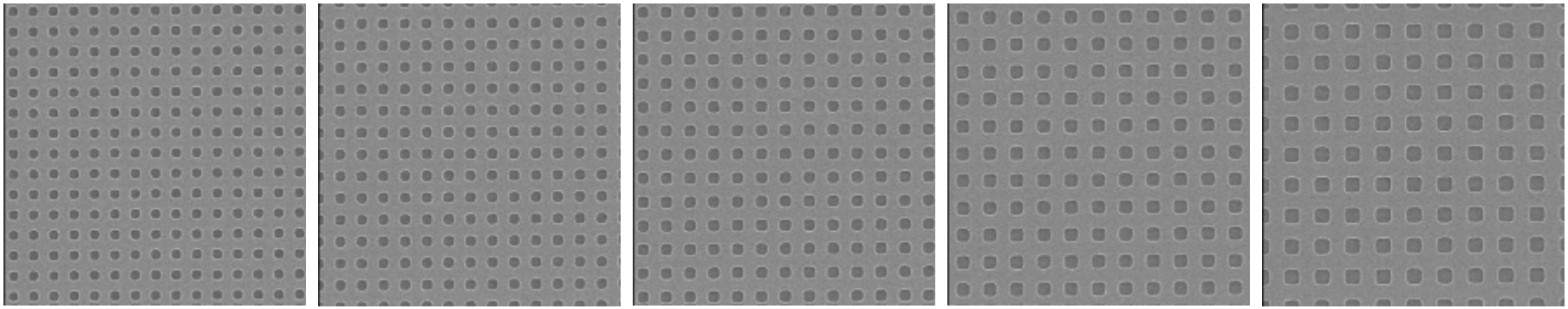


(2) Aerial Image of Dense C/H

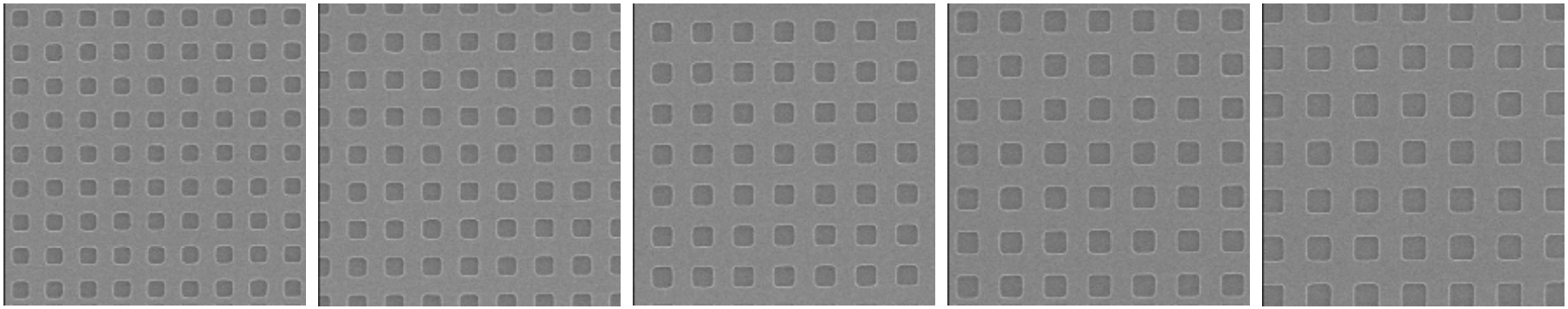
<Simulation conditions> Aberration: 0.76 nm RMS Flare: 0%
Illumination : Annular (σ=0.3/0.5) Mask structure: 2D

Effect of aberration might be also small for Dense C/H patterns.

Mask Pattern Shapes of Dense C/H Patterns



150 nm C/H | 160 nm C/H | 175 nm C/H | 200 nm C/H | 225 nm C/H

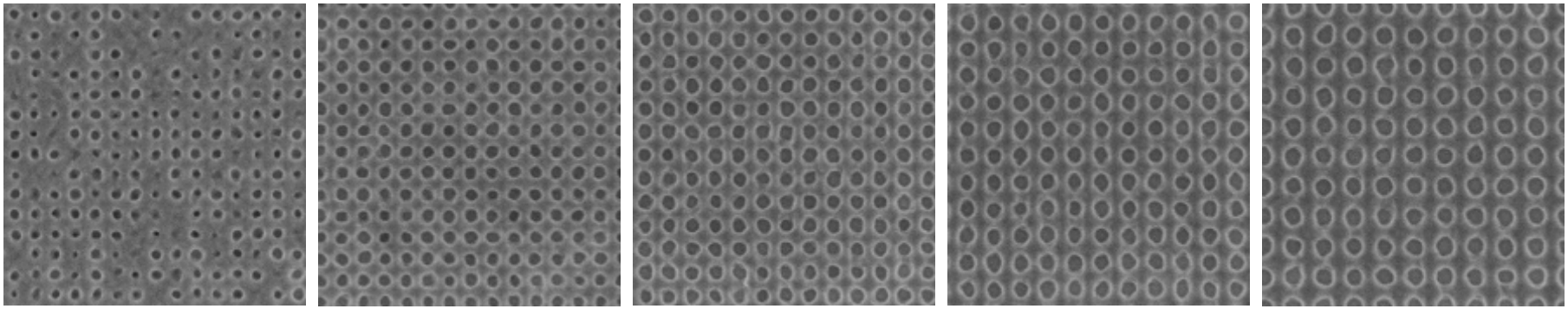


250 nm C/H | 275 nm C/H | 300 nm C/H | 325 nm C/H | 350 nm C/H

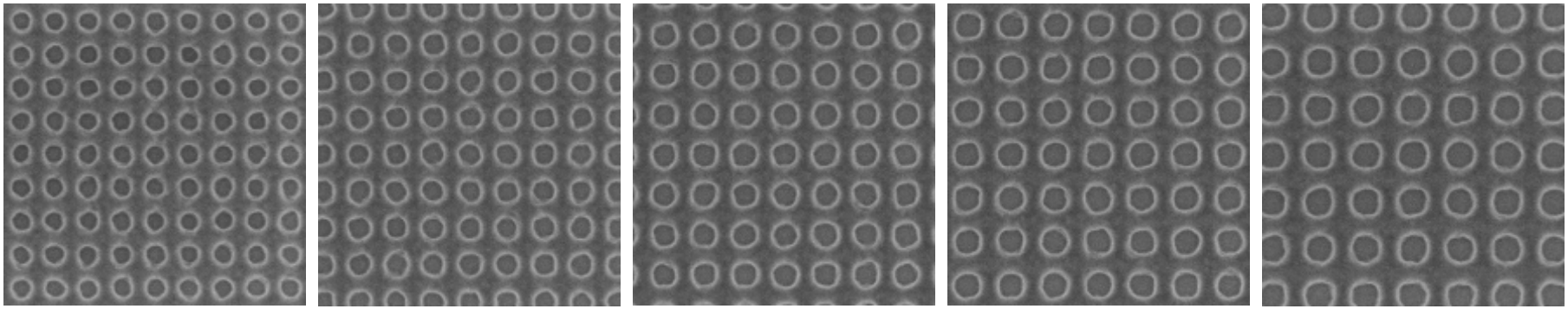
Mask structure: LR-TaBN(70nm)/CrN(10nm)/ML(40pairs)/Quarz

Mask patterns were resolved down to 150 nm C/H patterns.

Resolution of Dense C/H Patterns

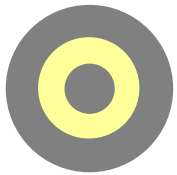


30 nm C/H | 32 nm C/H | 35 nm C/H | 40 nm C/H | 45 nm C/H



50 nm C/H | 55 nm C/H | 60 nm C/H | 65 nm C/H | 70 nm C/H

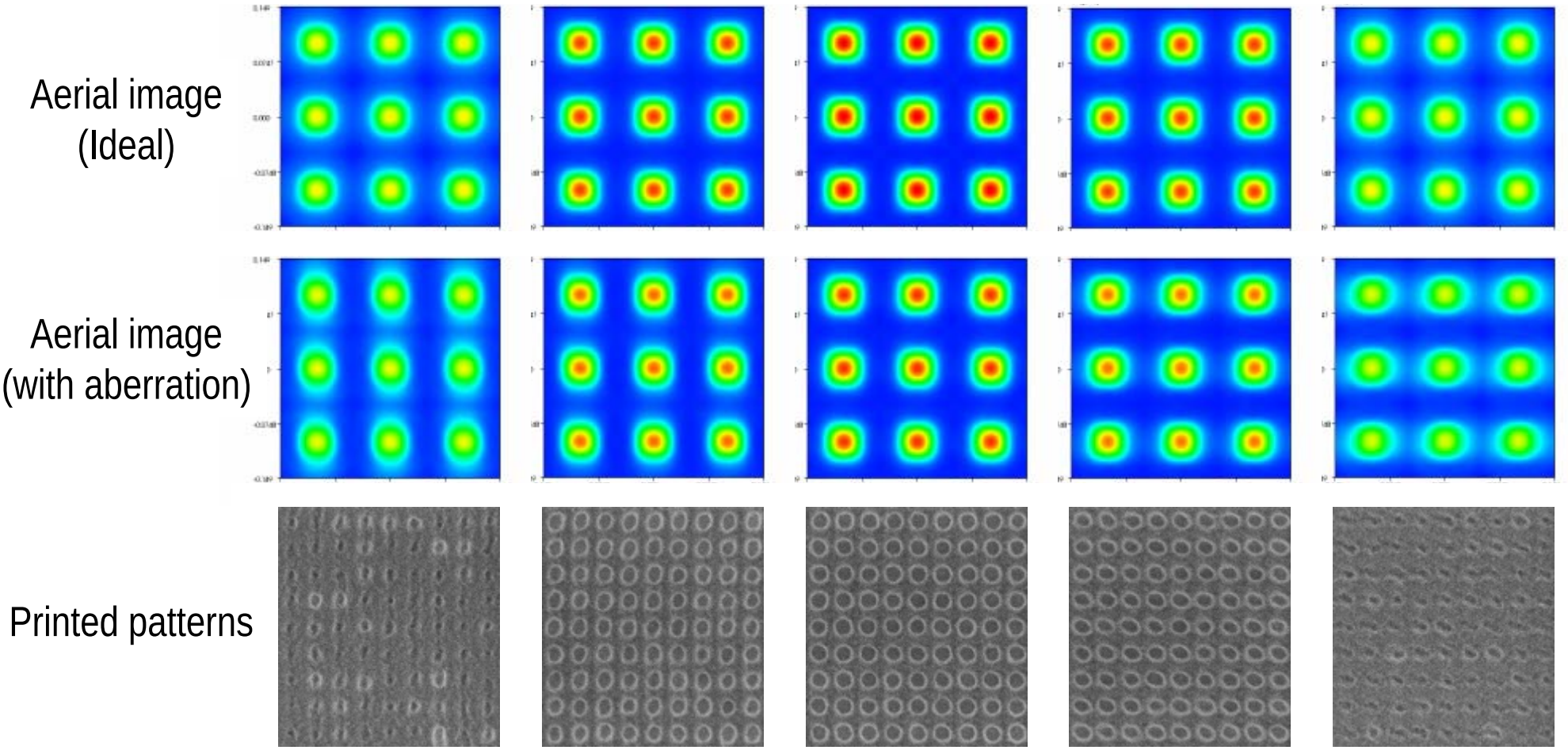
Resist: SSR2 (60 nm^t)



Annular
(σ=0.3/0.5)

Dense 32 nm C/H patterns were almost resolved.
Resolution might be limited by resist characteristics.

Defocus Characteristics of 50 nm C/H Patterns

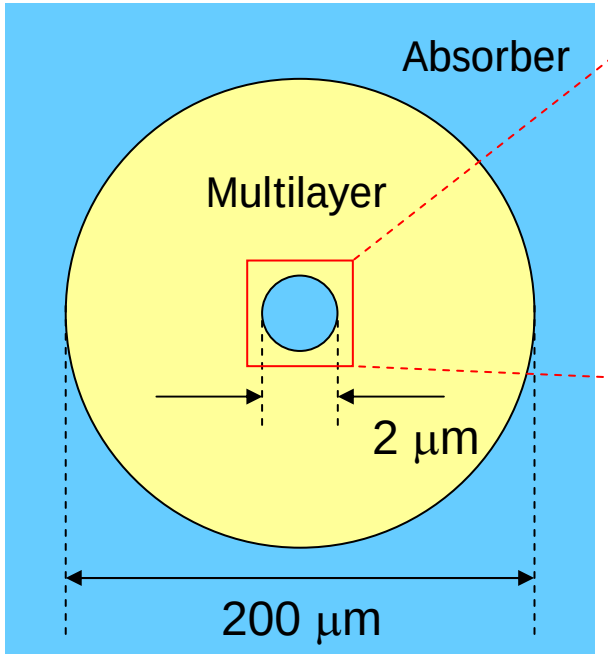


-100 nm | -50 nm | ±0 nm | +50 nm | +100 nm

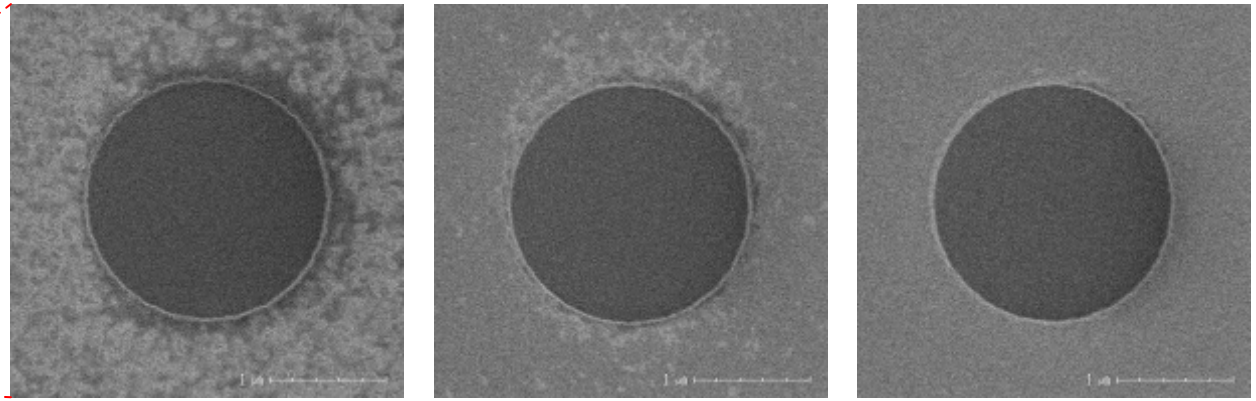
Defocus

Due to the astigmatic aberration, the shapes of C/H patterns were deformed at defocused point. However, the shapes were almost circle at best focus point.

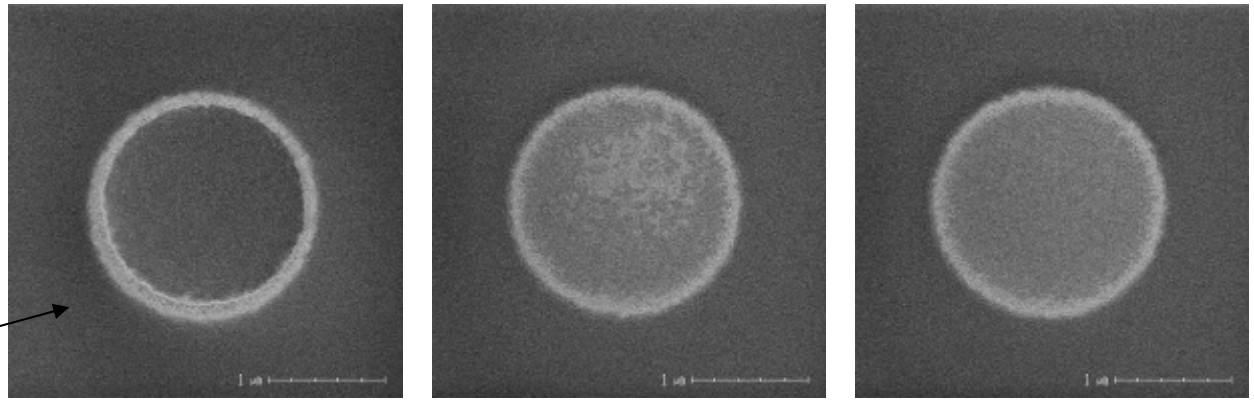
Measured Flare of SFET Optics (Kirk Method)



Pattern layout



9.3 mJ/cm^2 | 9.8 mJ/cm^2 | 10.2 mJ/cm^2 (D_0)



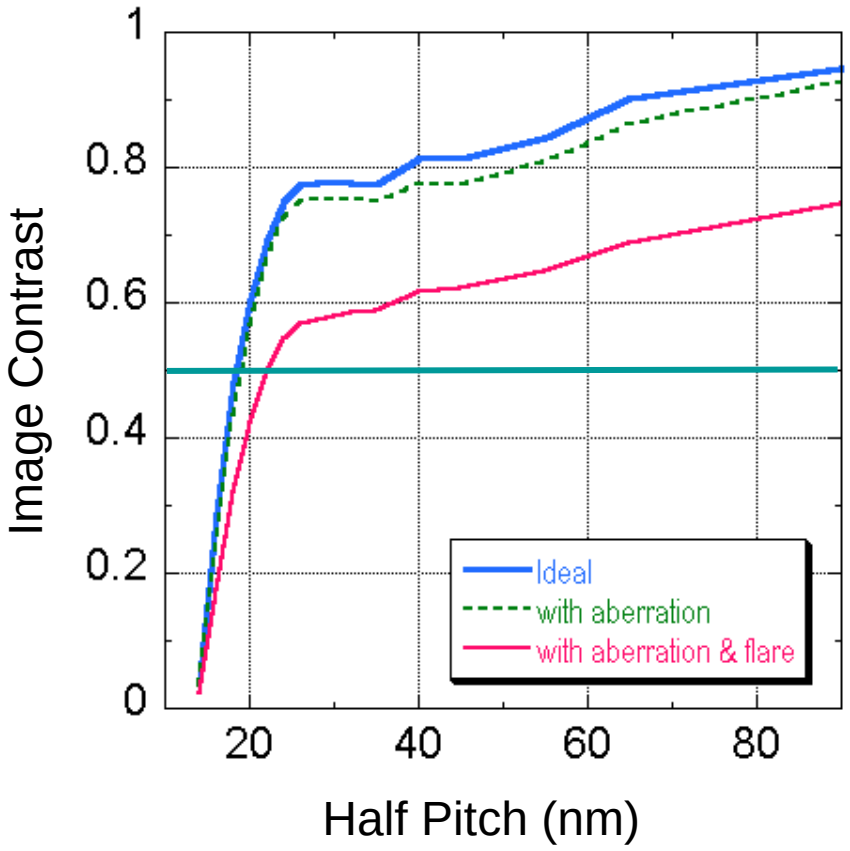
Very high dose changed positive resist to negative one.

66.6 mJ/cm^2 | 88.8 mJ/cm^2 | 93.2 mJ/cm^2 (D_1)

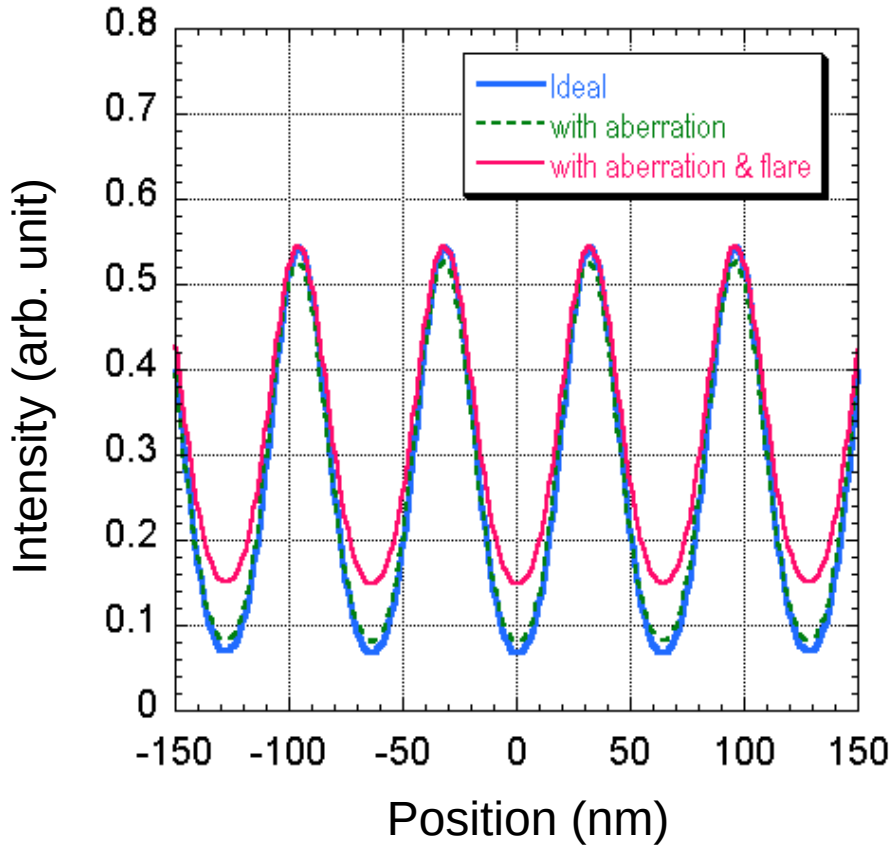
$$\text{Flare} = \frac{D_0}{D_1} = 11\%$$

Measured flare was 11% (Flare range was 1~100 μm).

Effect of Flare on Image Contrast (L/S)



(1) Image Contrast of L/S patterns



(2) Aerial Image of 32 nm L/S

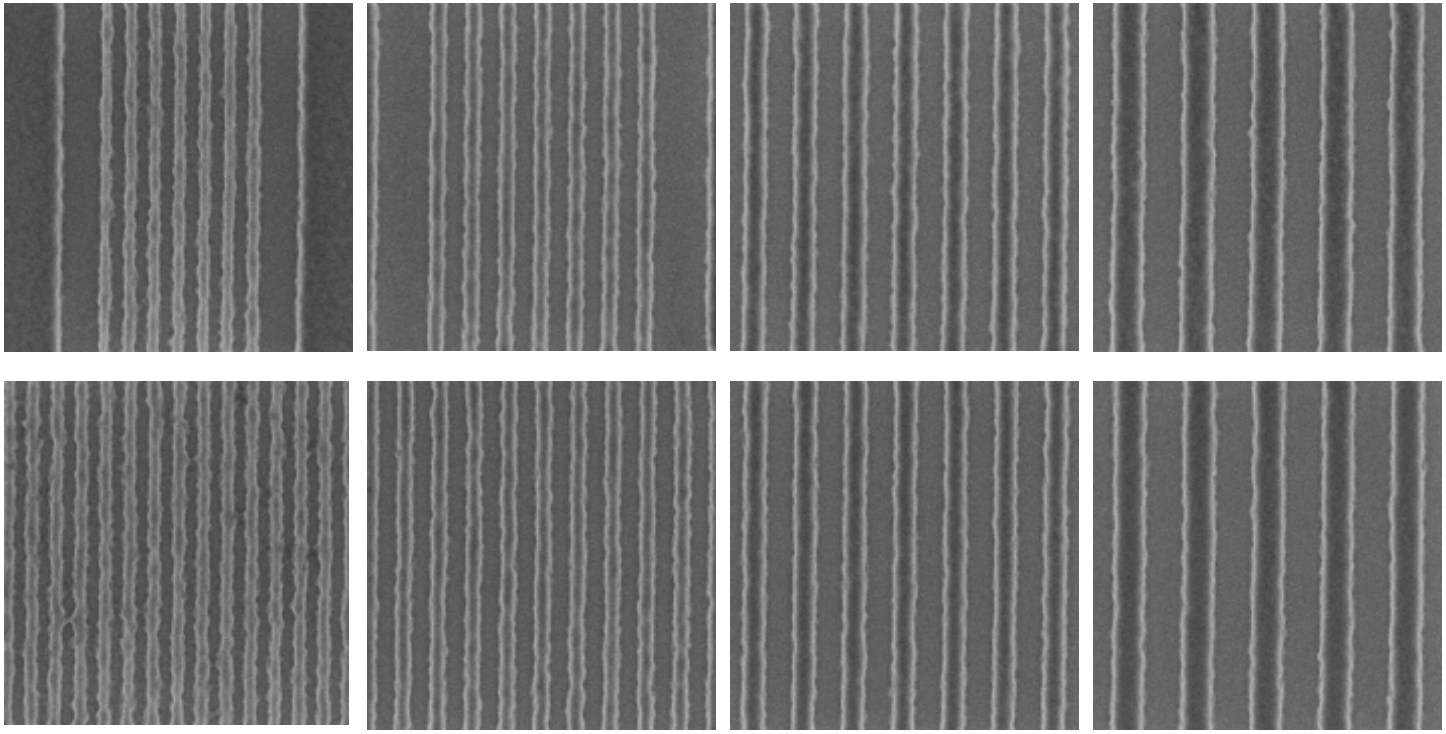
<Simulation conditions> Aberration: 0.76 nm RMS (AZ37) Flare: 11%(Constant)
Pattern density: 100% Illumination: Annular (σ=0.3/0.7) Mask structure: 2D

Effect of flare on image contrast might be quite large for L/S patterns.

Comparison of Dark-field & Bright-field Patterns

Dark-field patterns
（Density:＜10%）

Bright-field patterns
（Density:＞85%）

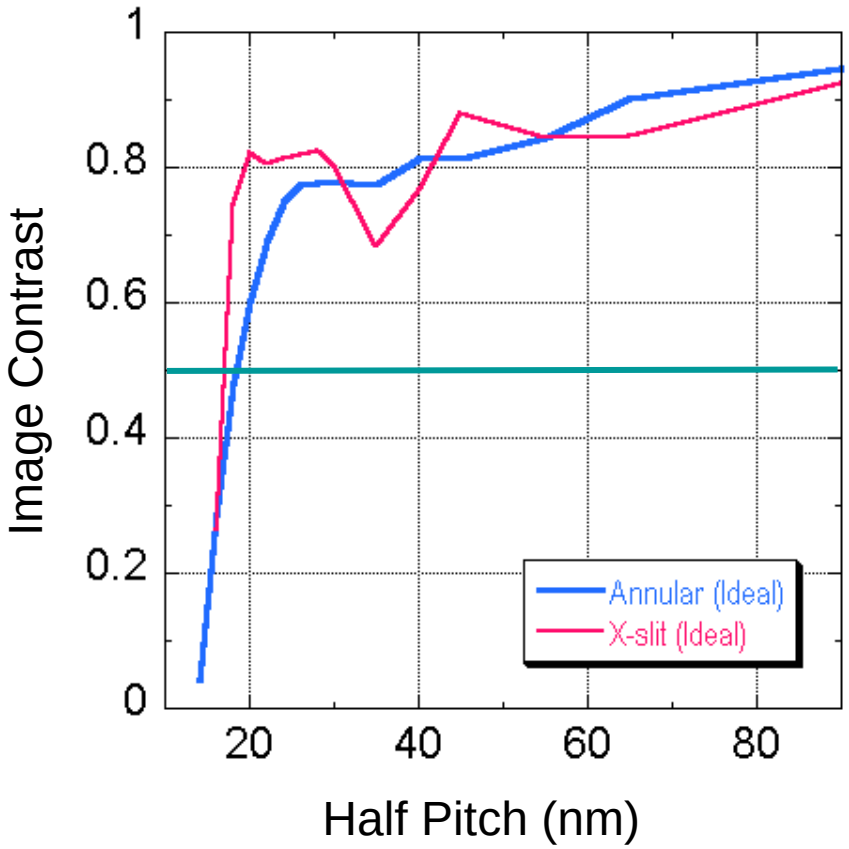


32 nm L/S | 45 nm L/S | 65 nm L/S | 90 nm L/S

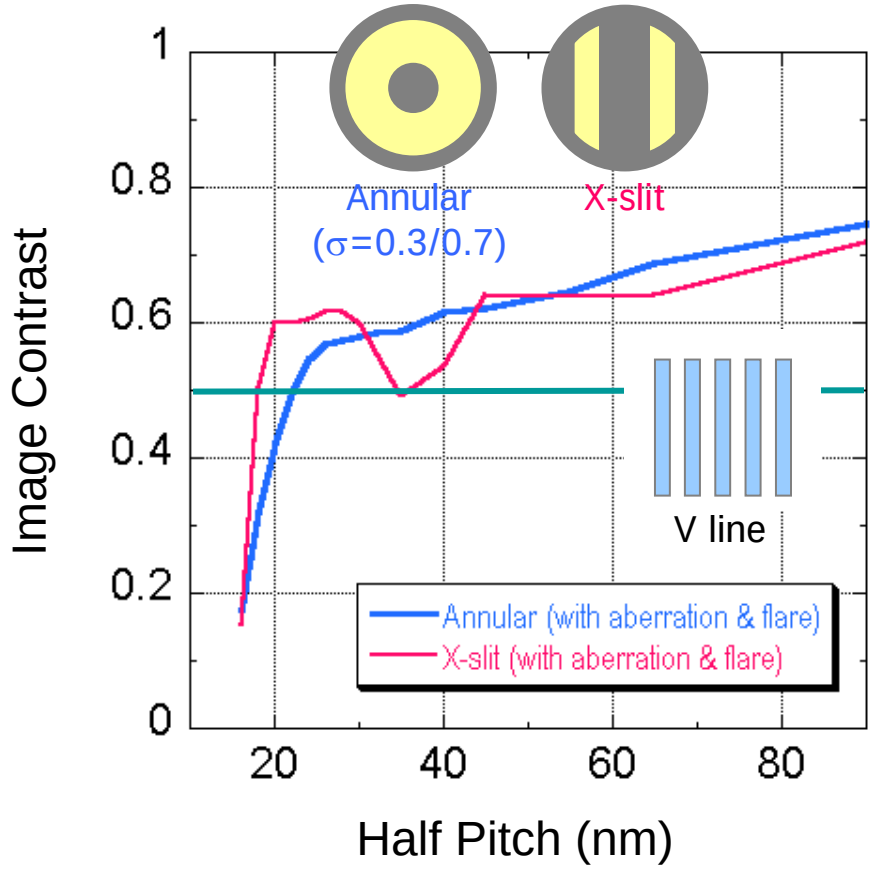
Illumination: Annular (σ = 0.3/0.7)
Resist: SSR2 (60 nm^t)
Dose: 24 mJ/cm^2

The effect of flare on printed L/S patterns was unclear.
We are making further analysis.

Resolution Enhancement by slit Illumination



(1) Ideal

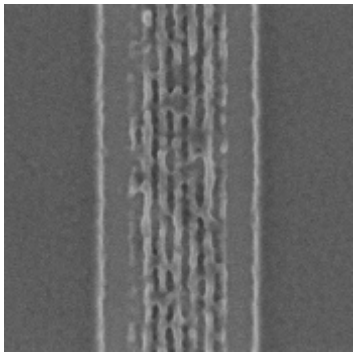


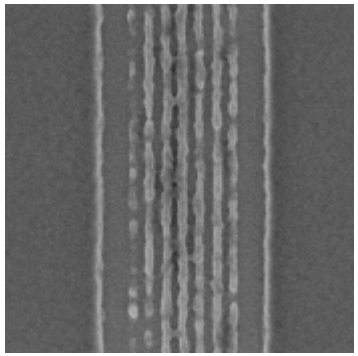
(2) with aberration & flare

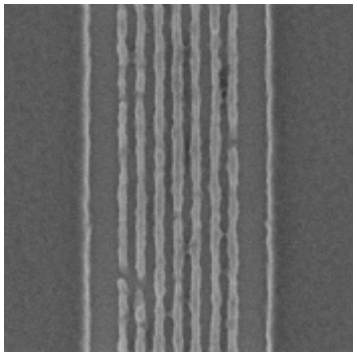
<Simulation conditions> Aberration: 0.76 nm RMS (AZ37) Flare: 11%(Constant)
Pattern density: 100% Illumination: Annular (σ=0.3/0.7) Mask structure: 2D

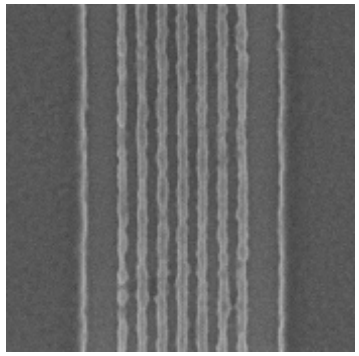
Image contrast of 20-30 nm L/S might be improved by using slit illumination.

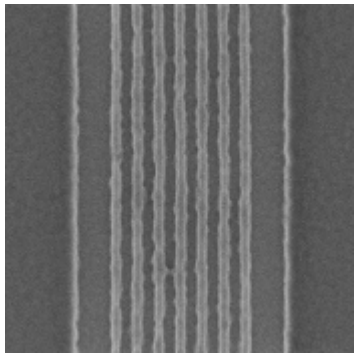
Resolution of L/S patterns (X-slit)

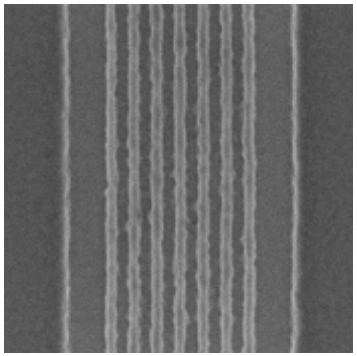

20 nm L/S

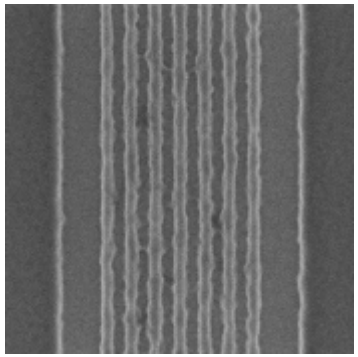

22 nm L/S

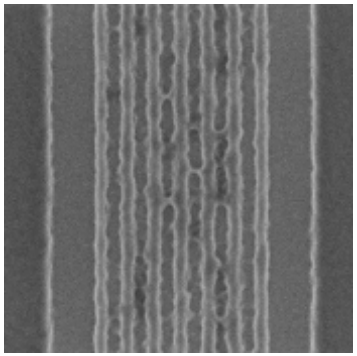

24 nm L/S

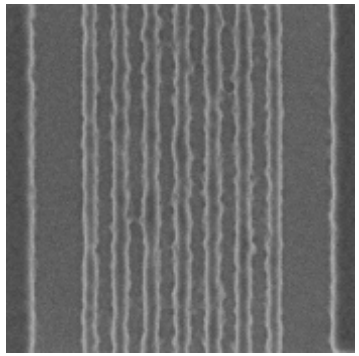

26 nm L/S

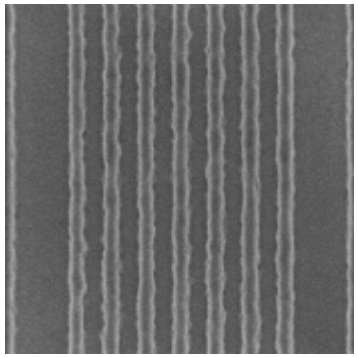

28 nm L/S


30 nm L/S

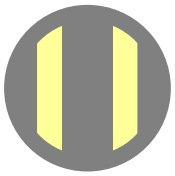

32 nm L/S


35 nm L/S


40 nm L/S


45 nm L/S

Resist: SSR2 (60 nm^t)


X-slit

Pattern shapes of 20-26 nm L/S patterns were improved by using slit Illumination. 24 nm L/S patterns were almost resolved.

Conclusions

- We confirmed that SFET can resolve 26 nm L/S and 32 nm C/H under annular illumination and 24 nm L/S under slit illumination. Resolution might be limited by resist characteristics.
- Simulation results indicated that the effect of aberration on the image contrast of L/S and C/H patterns might be small.
- Due to astigmatic aberration, focus shift of about 60 nm was observed between horizontal and vertical L/S patterns.
- Due to small spherical aberration, focus shift among various sizes of L/S patterns might be less than 20 nm.
- The measure flare was 11% (Flare range was 1~100 μm).
- Although the effect of flare on the image contrast might be quite large, the difference between printed dark-field and bright-field L/S patterns was unclear.

Acknowledgements

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