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Design, fabrication, and test of an EUV mask imaging microscope for lithography generations with sub-16 nm half pitch

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Outline

1. **Motivation**

   Optics for high-magnification EUV microscopy

2. **Experimental**

   Full-field microscope for at-wavelength observation

3. **Highlight data**

   EUV images of sub 16-nm generation mask

4. **Summary and future plans**

1. Motivation

EUV optics research on Tohoku Univ.

Mirror fabrication

①Substrate polishing

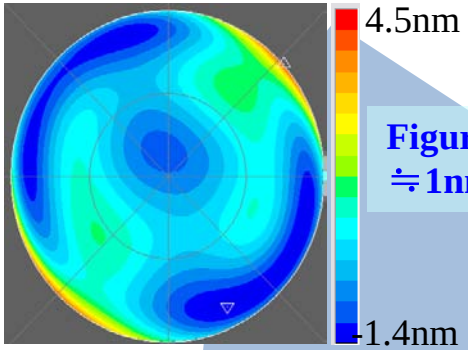
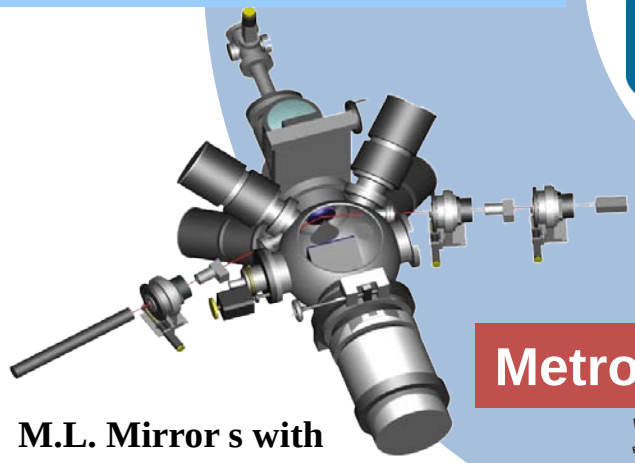


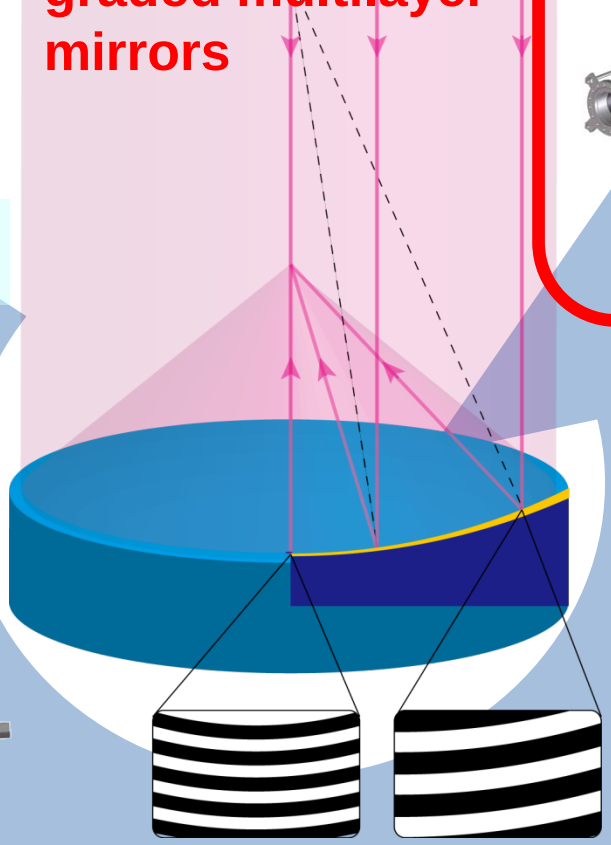
Figure error
≒1nm

②Multilayer evaporation

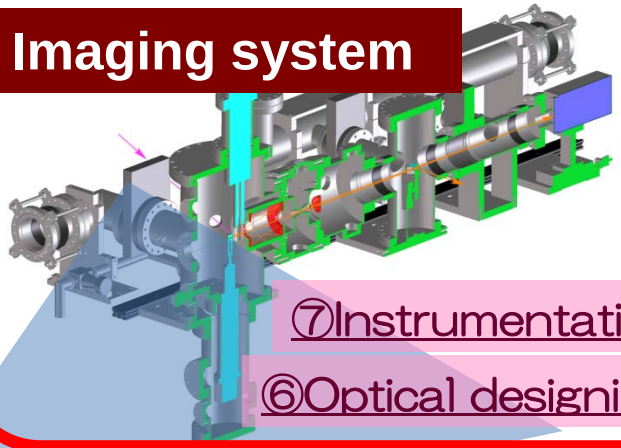


M.L. Mirror s with
graded thickness control
Layer thickness error <0.3%
(across 100mm diameter)

Imaging optics with graded multilayer mirrors



Imaging system



⑦Instrumentation

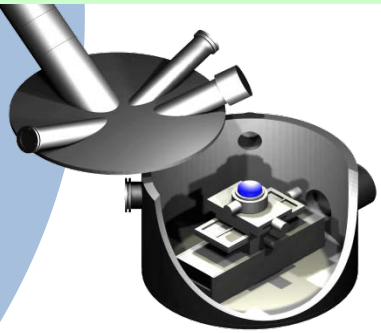
⑥Optical designing

Phase control

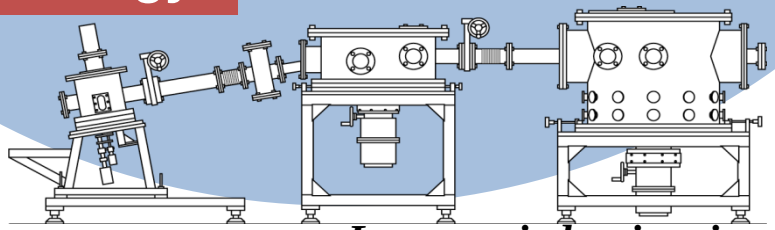
⑤Wave front correction

Phase
modification
based on
wave optics

Phase step
＜0.1nm

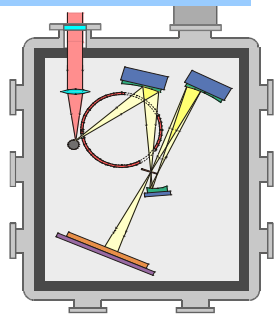


Metrology



④EUV Interferometory

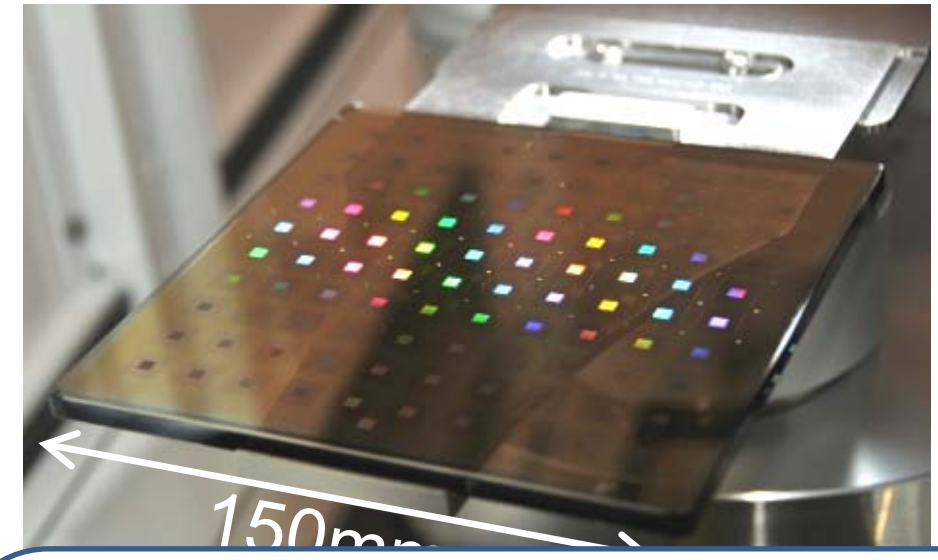
Repeatability
＜0.1nm

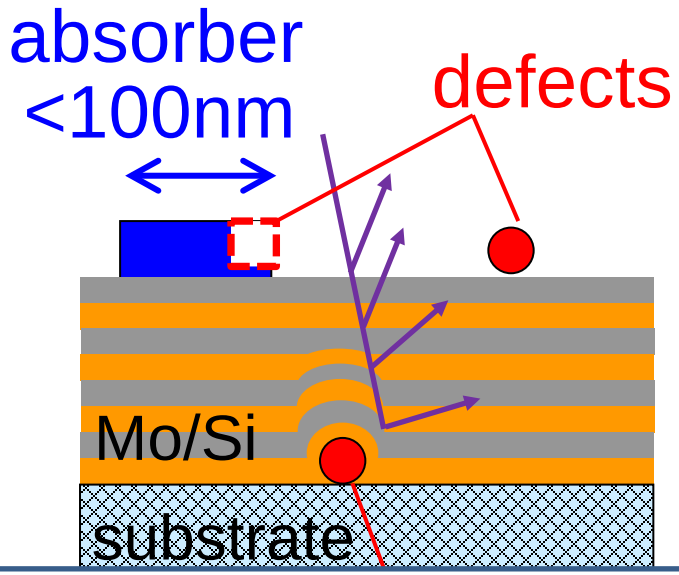


③Reflectivity measurement

Layer period estimation with pm
accuracy error<±0.02%

At-wavelength inspection of EUVL mask





Aim of this work

Innovative EUV imaging system realizing both

✓**high spatial resolution for sub 16-nm node mask,**

✓**wider field of view for practical inspection time.**

Research Team

Tohoku Univ.

M. Toyoda, K. Yamasoe, M. Yanagihara

✓*Imaging system: Design, Fabrication*

Univ. of Hyogo

A. Tokimasa, T. Harada,

T. Watanabe, H. Kinoshita

✓ *EUV source: NewSUBARU*

✓ *Mask handling*

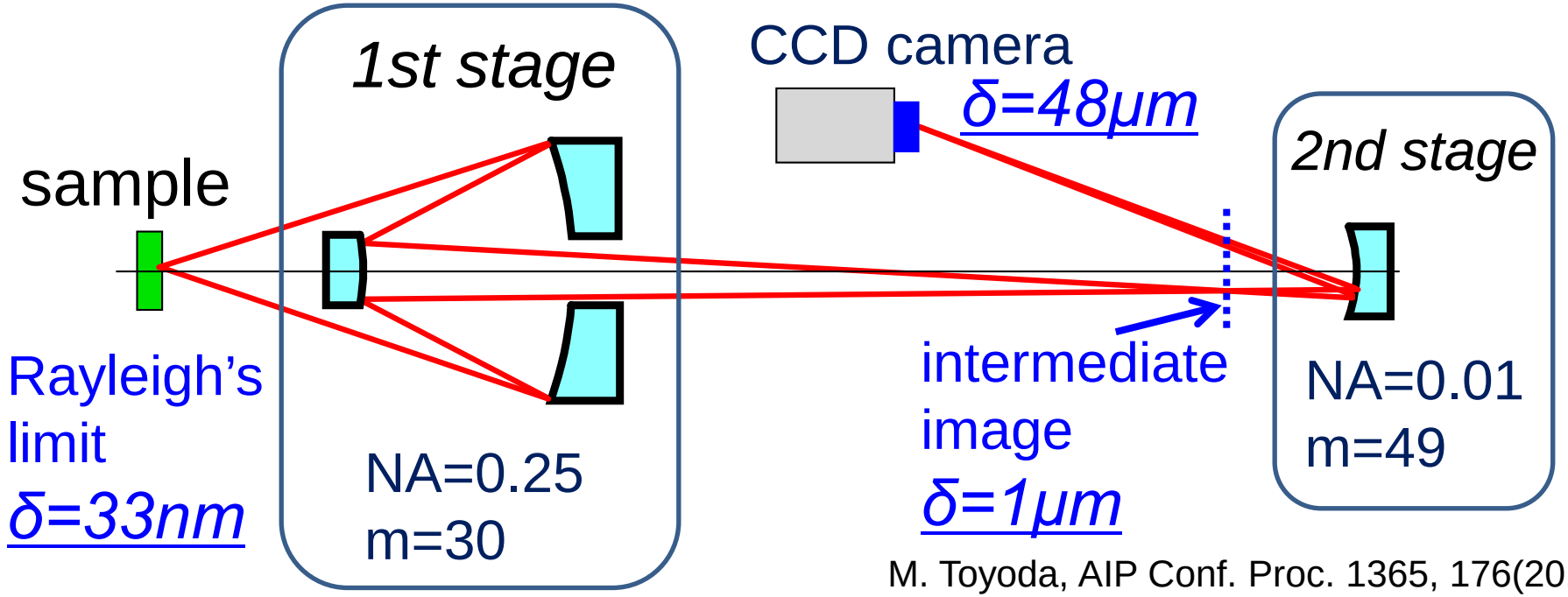
EIDEC

T. Amano, T. Terasawa

✓ *Test mask fabrication*

2. Experimental

Two-stage imaging system for high magnification



M. Toyoda, AIP Conf. Proc. 1365, 176(2011).
M. Toyoda, Japan Patent 2010-79257.

✓Higher magnification (m=1460)

⇒ ***Resolution of 30nm with EUV-CCD camera***

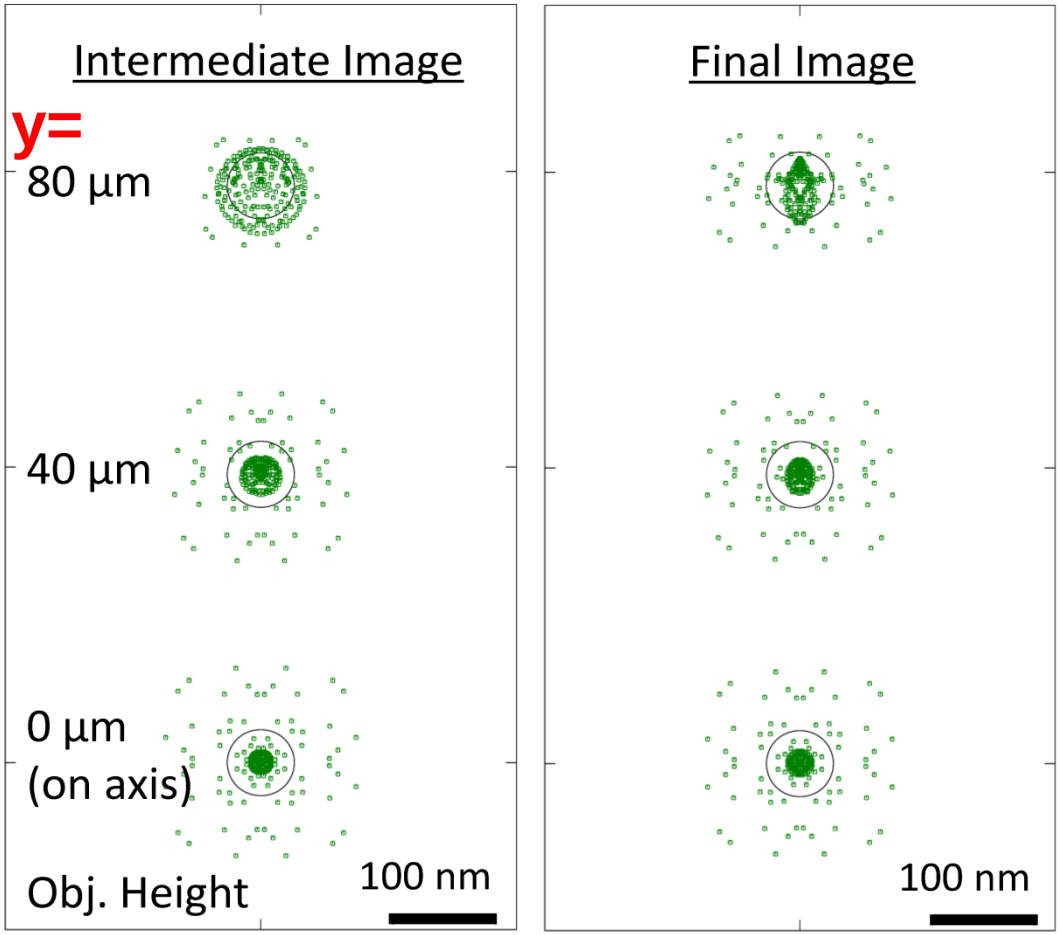
✓Good *correction of off-axis aberrations*

Aberration correction on the 2nd-stage optics

Seidel aberrations

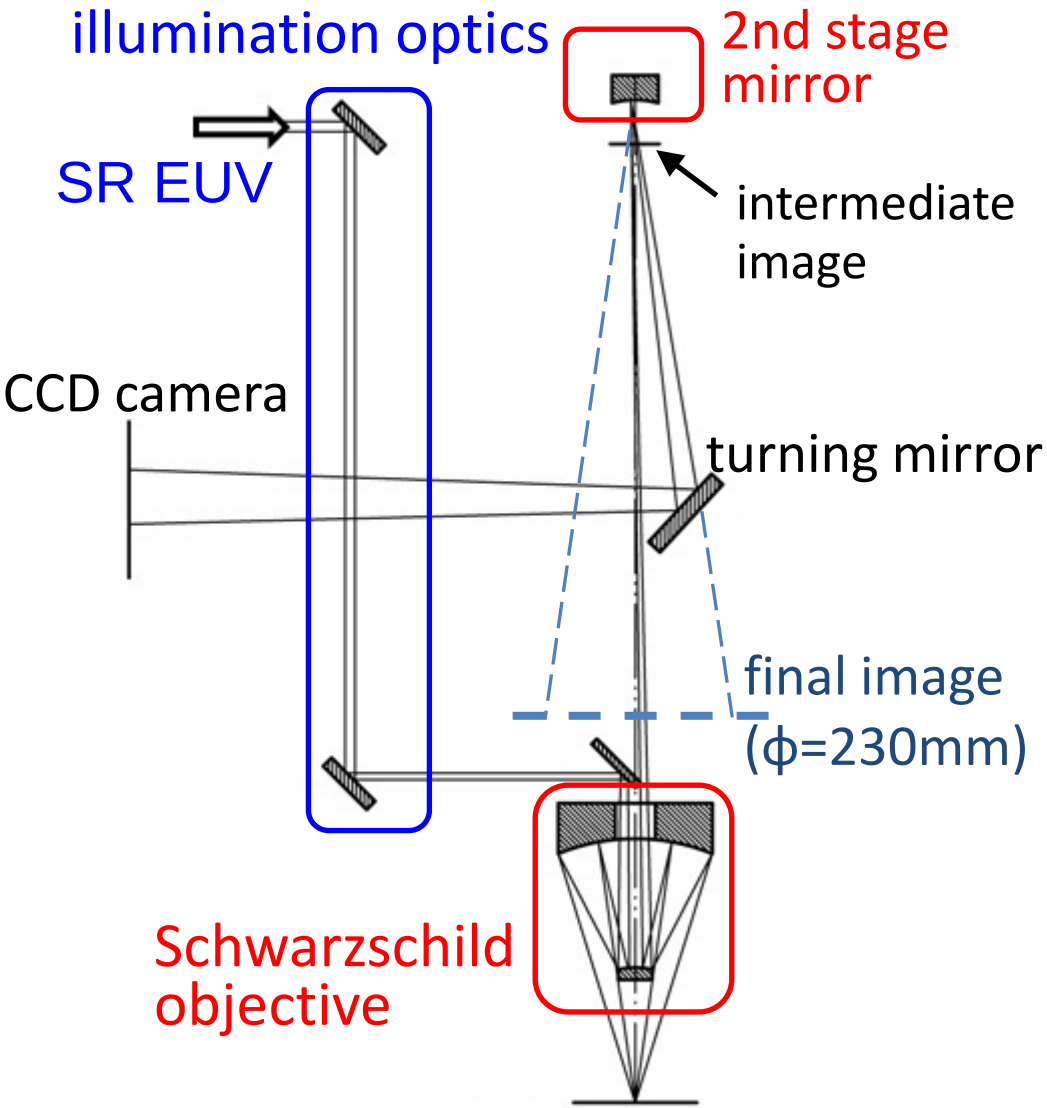
	1st+2nd
Spherical NA^4	○
Coma $y\ NA^3$	○
Astigmatism $y^2\ NA^2$	○
Petzvar $y^2\ NA^2$	○

Spot diagrams



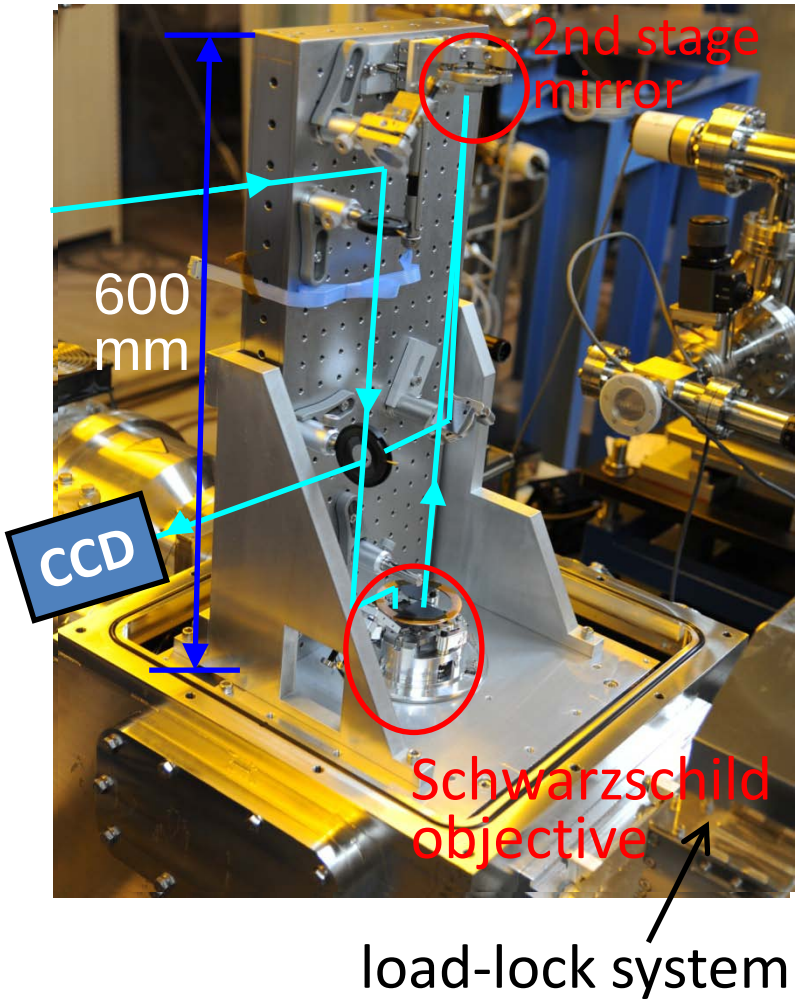
✓ ***Wider field of view can be expected (Φ=160µm)***

Experimental setup of the novel imaging system



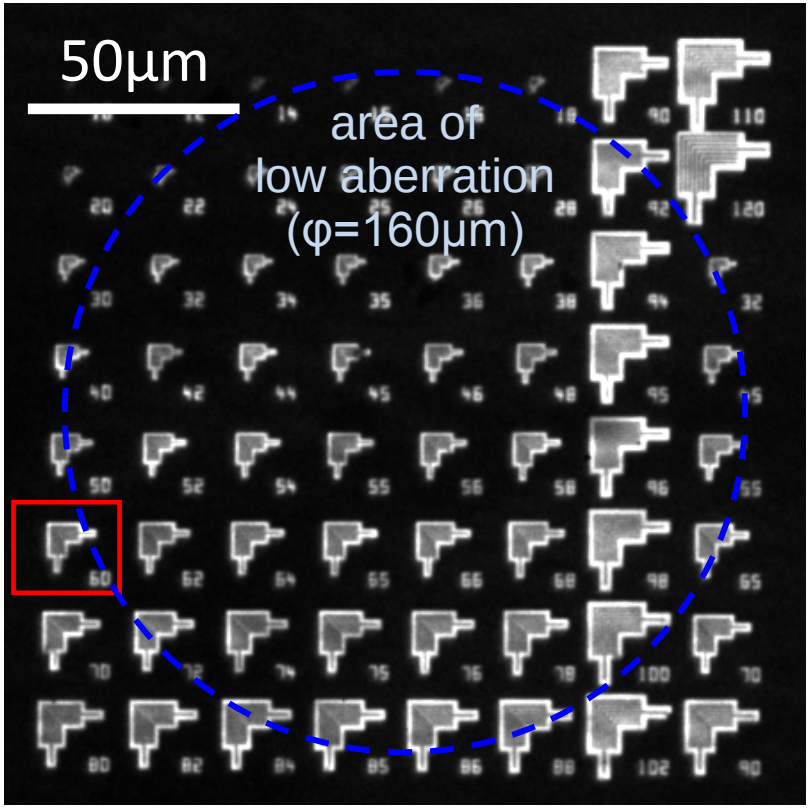
EUVL mask (F.O.V.: ϕ=160μm)

NewSUBARU BL3



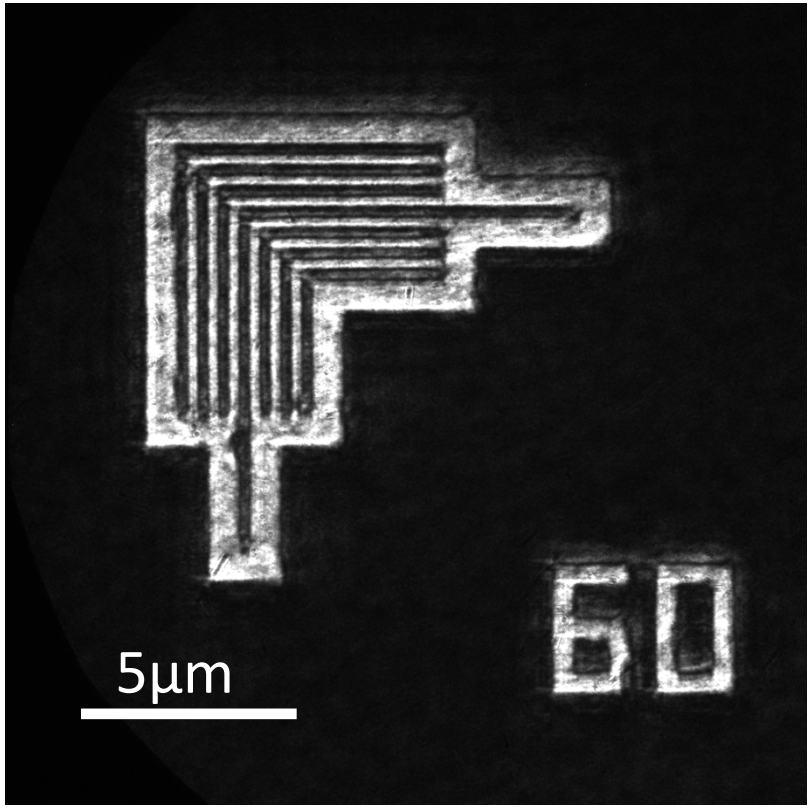
3. Highlight data

Confirmation of the magnification enhancement



Intermediate image (m=30)

Exp. time: 0.25 sec.



Final image (m=1460)

Line width: 240nm (60nm)

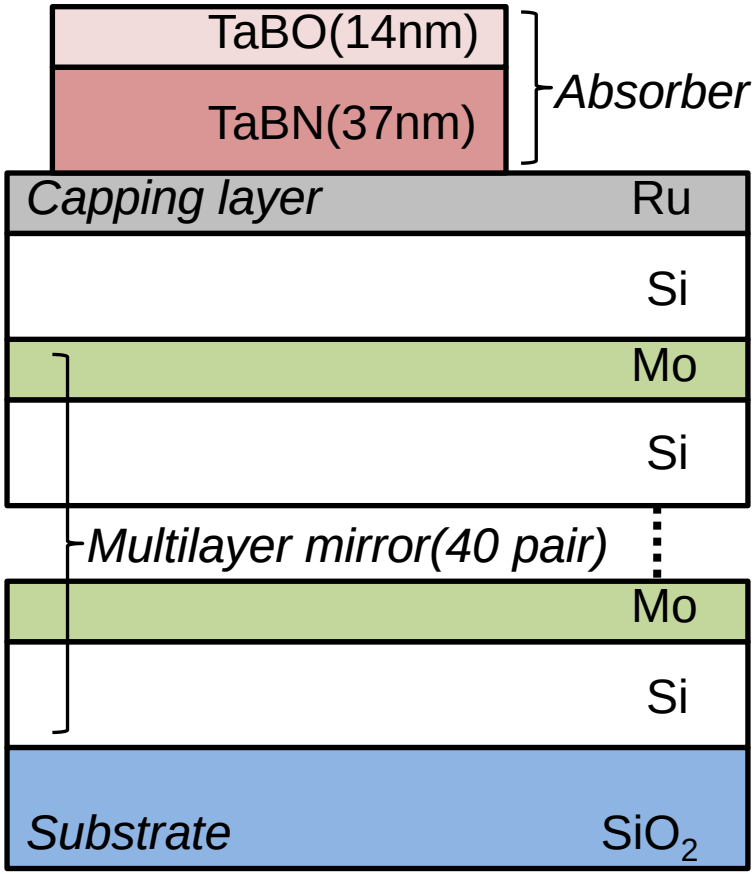
Exp. time: 36 sec.

EUV-CCD camera: pixel size 13.5μm, 2048 × 2048 pixels

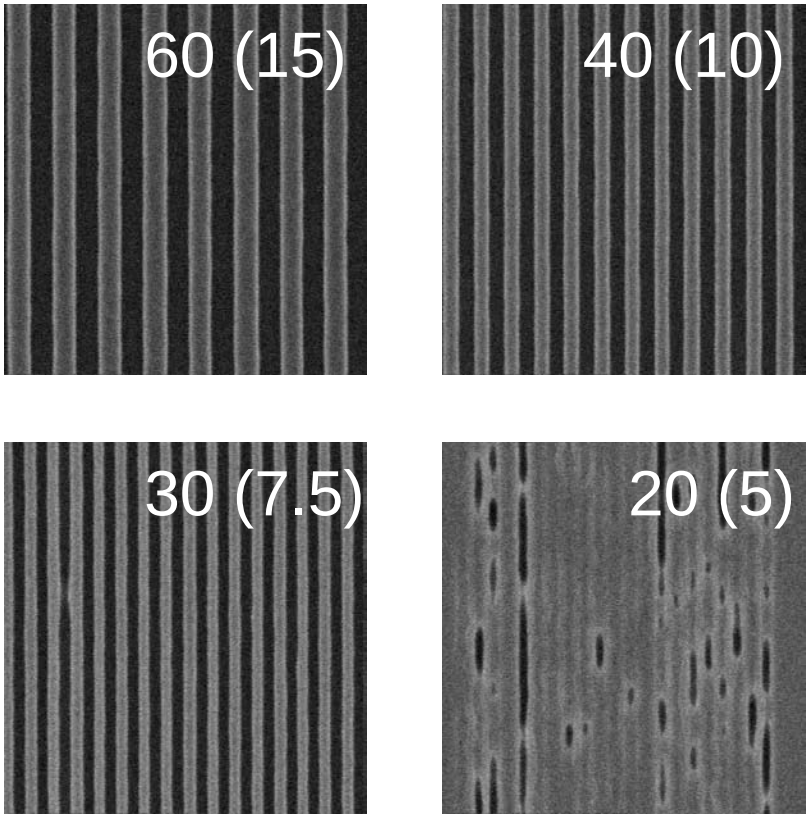
M. Toyoda et.al., Appl. Phys. Express **5** (2012) 112501

Resolution measurement with L/S patterns

Mask configuration

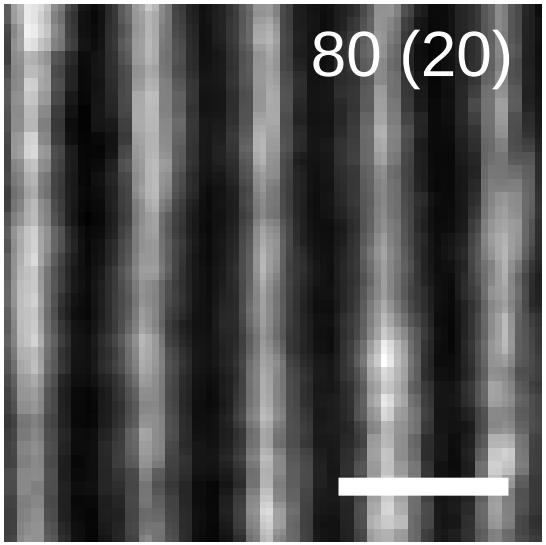


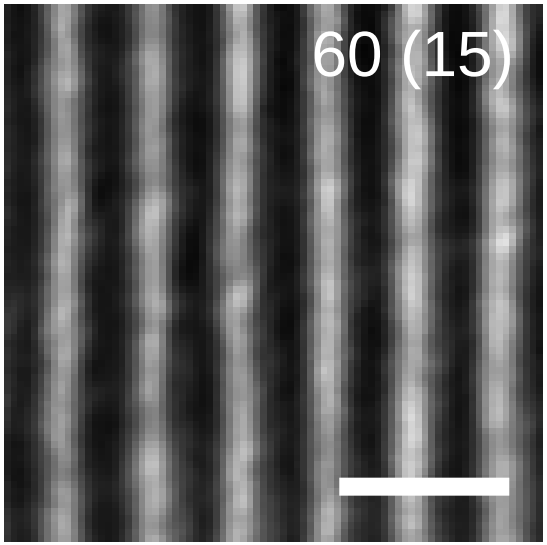
SEM Images

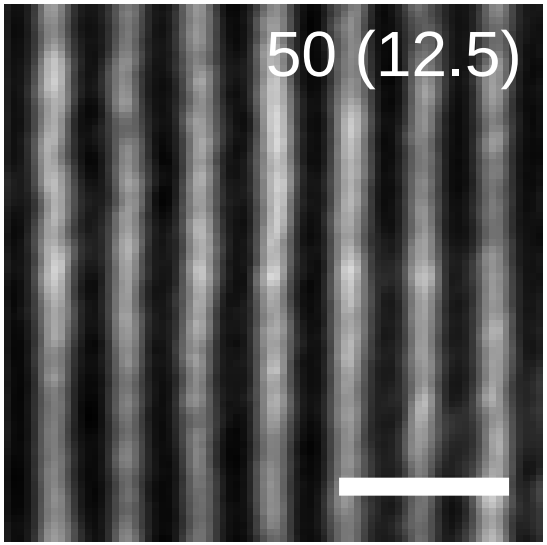


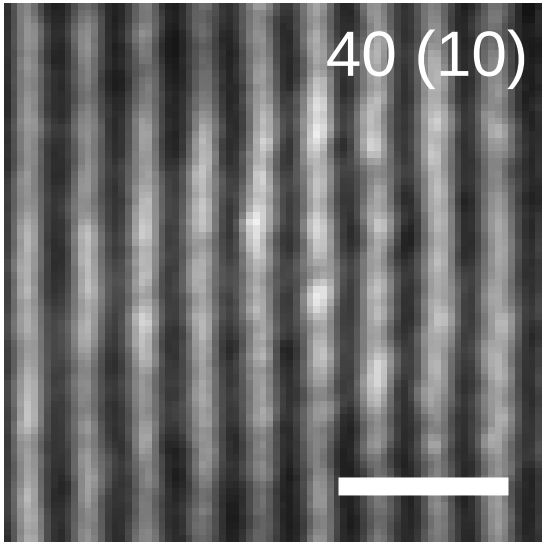
- ✓ Test mask made by DNP
- ✓ Fine L/S patterns between 100-nm to 20-nm half pitch
- ✓ 30-nm half pitch patterns were successfully fabricated

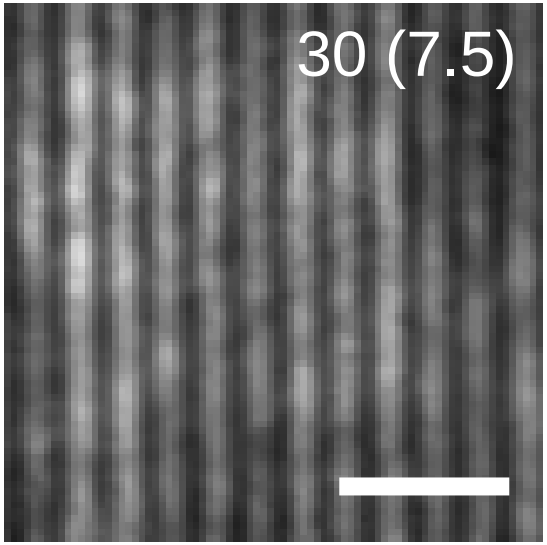
EUV images of sub-16 nm generation mask





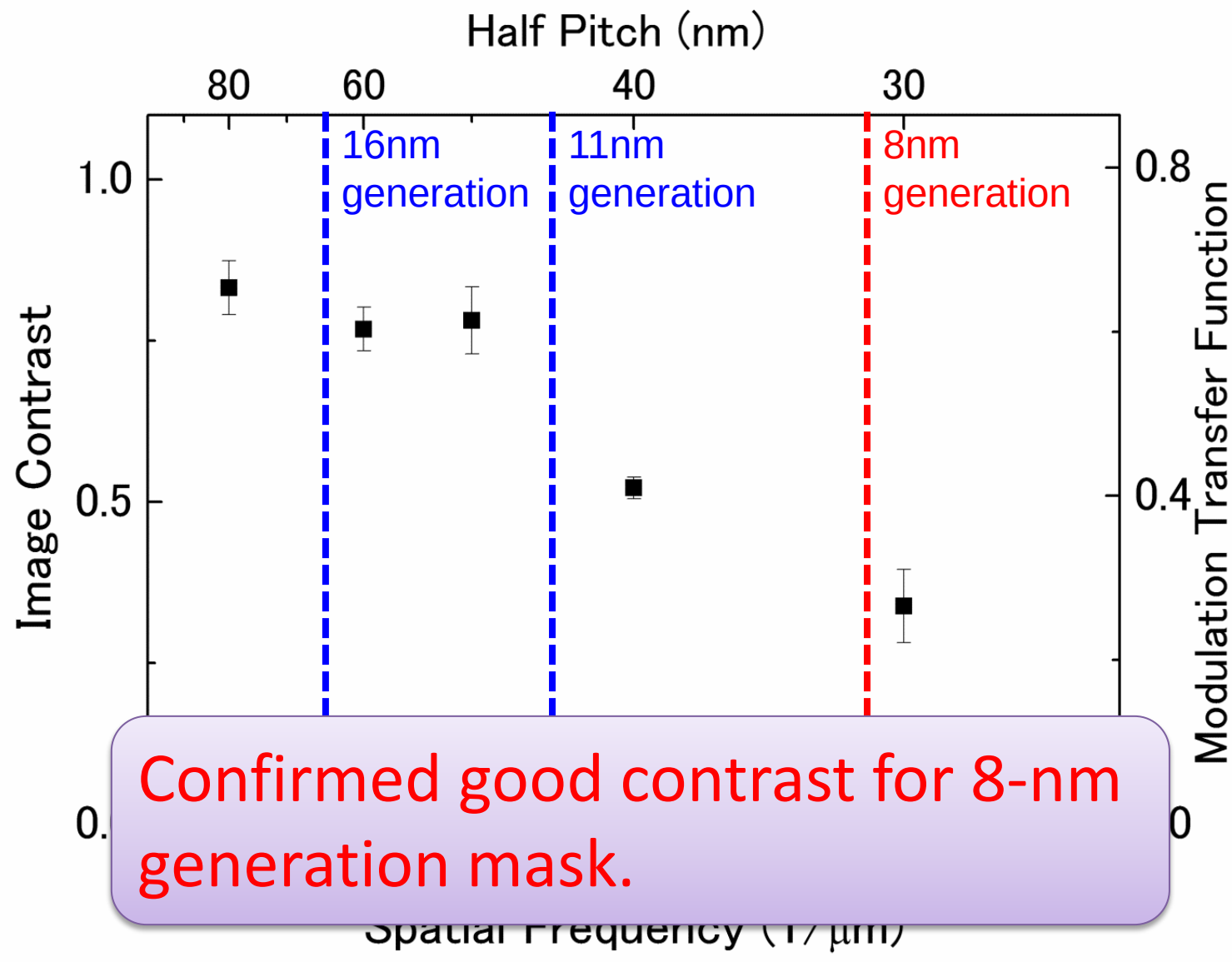






- ✓Scale bar: 200 nm
- ✓Pixel size: 9.2 nm
- ✓ 80 to 30-nm half pitch patterns were clearly resolved
- ✓Speckle noise due to high coherency

Image Contrast as a function of spatial frequency



Confirmed good contrast for 8-nm generation mask.

4. Summary

✓A high magnification EUV microscope based on all-reflective objective is proposed.

✓The objective is expected to have a large field of view of 160 μm.

✓ 30-nm wide L/S patterns are resolved with good contrast.

⇒ At-wavelength observation tool beyond 8-nm generation.

Future plans

✓At-wavelength observation of mask defects

✓Upgrade of the facility

An illumination optics with uniform intensity, coherence control

A large scale EUV-CCD camera for practical application

✓Lab-scale inspection tool with a plasma light source

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Thank you for your attention.