Actinic mask metrology for EUV Lithography

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The Outline

1) Introduce Actinic Mask Inspection system

2) Observation of finished EUVLmasks

3) Defects inspection by EUV microscope

4) Comparison of resolution for Cr and TaBN absorber layer

5) Pattern resolution for white and monochromatic light

6) Conclusion

Roadmap of the Mask Requirements

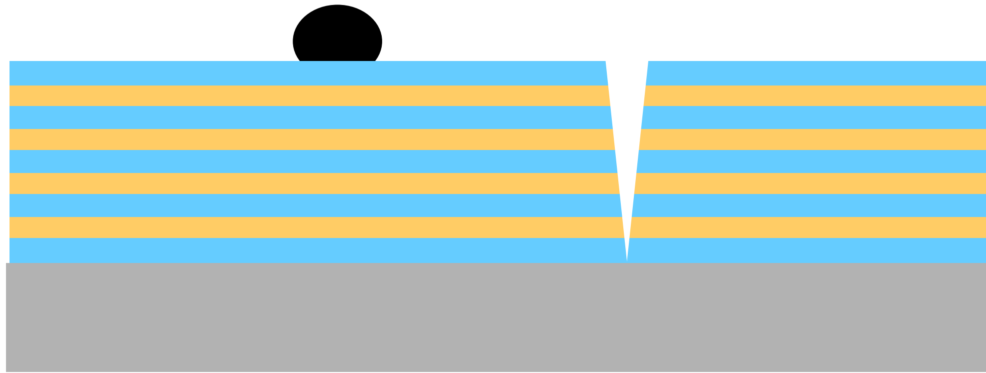
Year of Production	2006 70 nm	2007 65 nm	2010 45 nm	2013 32 nm	2016 22 nm
Wafer minimum half pitch (nm)	70	65	45	32	22
Mask Magnification	4	4	4	4	4
Mask minimum image size (nm)	160	140	100	72	52
Pattern Defect size (nm)	**55**	**50**	**35**	**25**	**15**
Substrate defect size (nm)	**39**	**37**	**32**	**27**	**23**
Absorber LER (3σ nm)	5	4	3	3	3

ITRS: 2001

Requirements of the Mask defect inspection

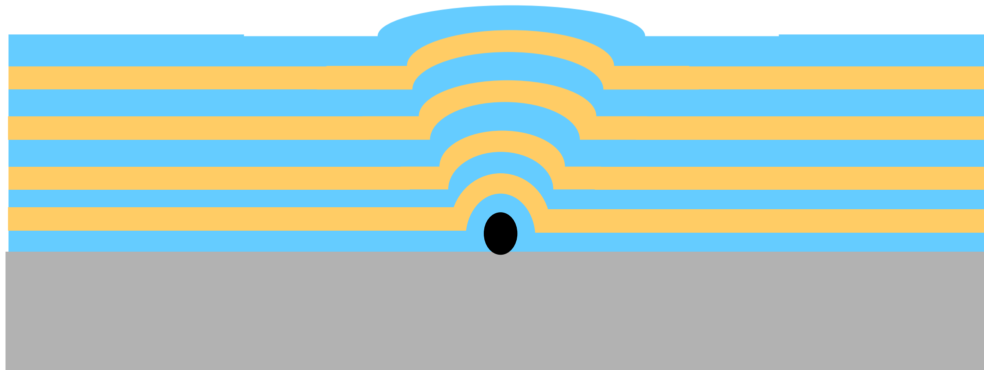
1) Detection of <30 nm size defect

2) Height resolution of <0.03 nm by Phase contrast interferometer



Critical defects:
>25 nm @32nm node
>15 nm @22nm node

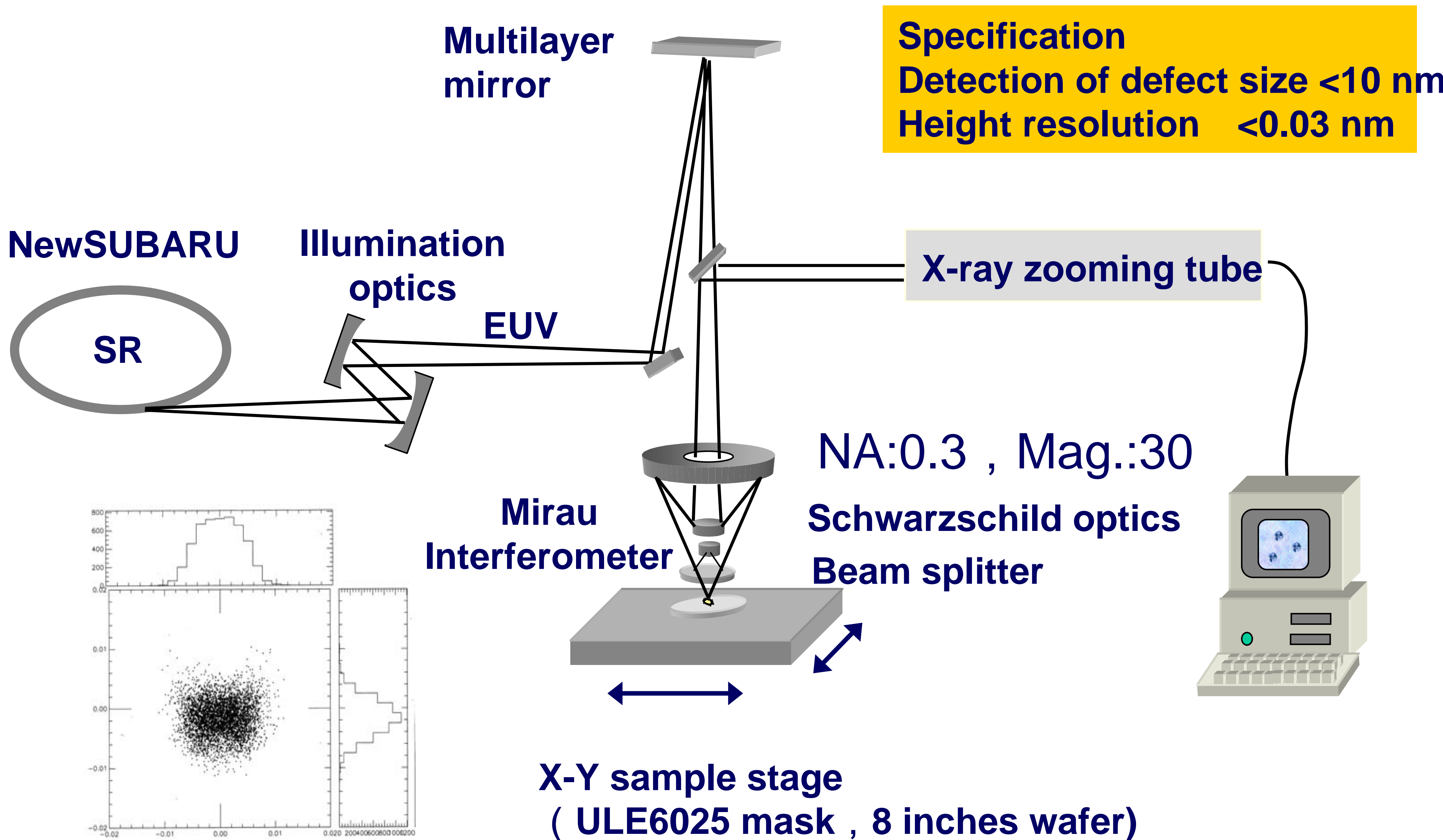
Intensity Defects



Critical defects:
5 nm height and
> 20 nm width

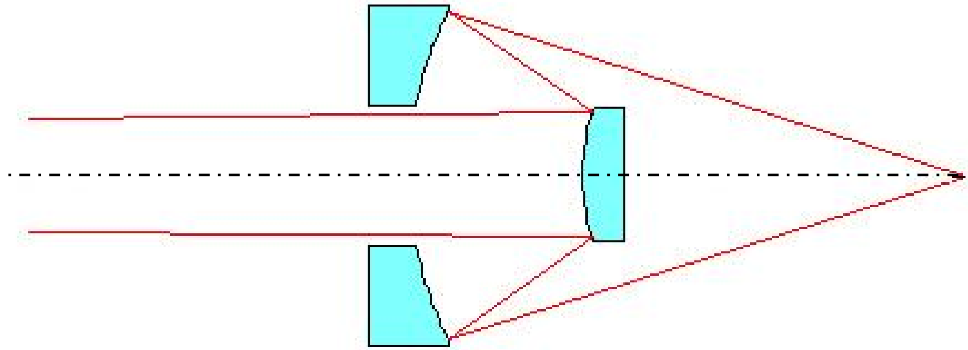
Phase Defect

EUV-Phase-Contrast Microscope （Under construction at HIT）



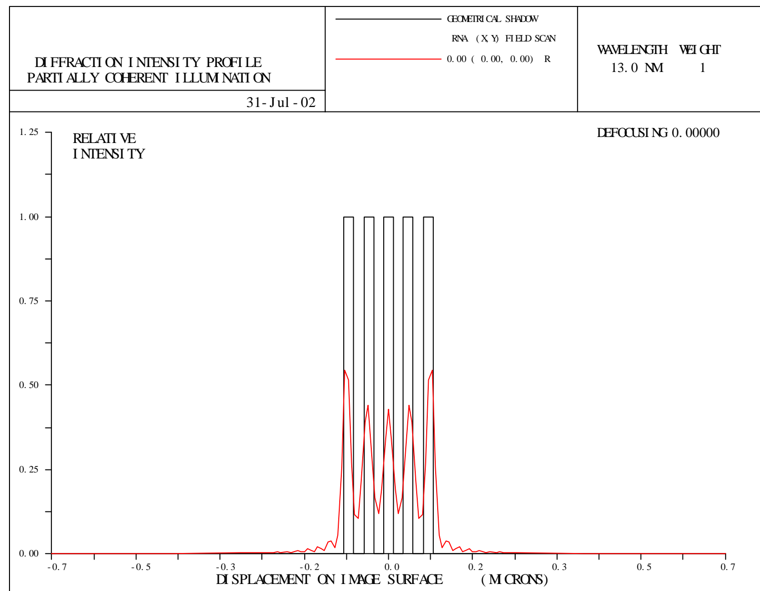
σ = 0.6 uniform NA

Design of the optics for EUV microscope



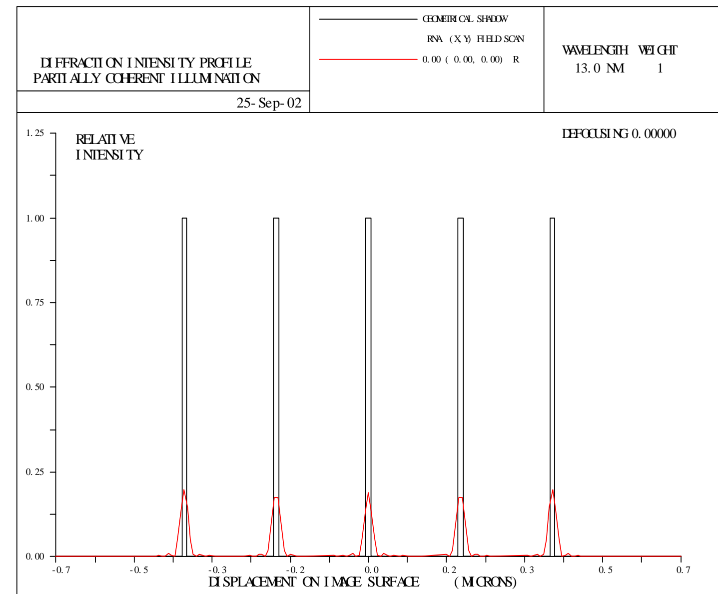
NA 0.3
30 ×

14: 14: 16



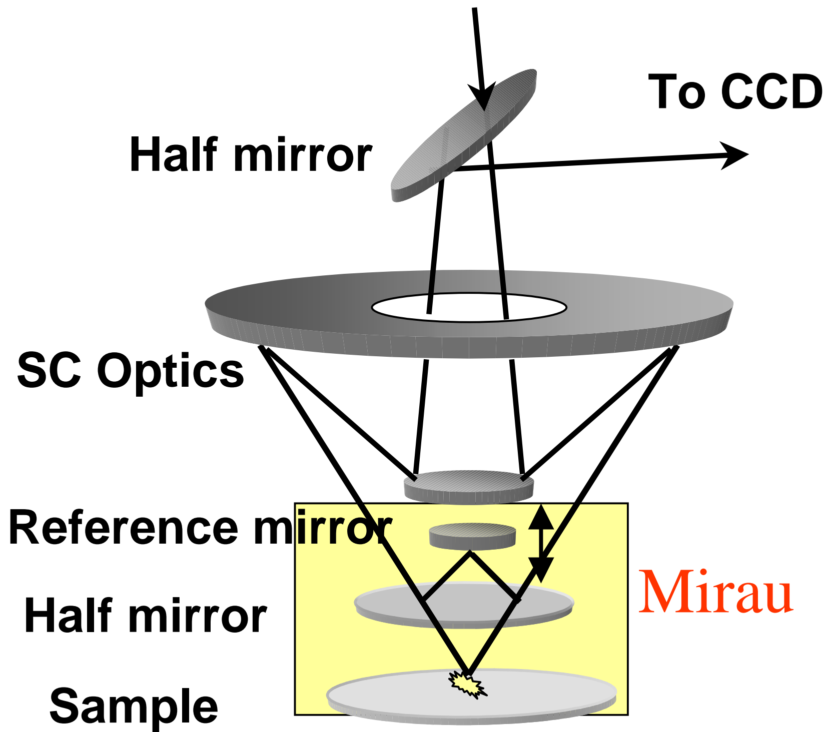
20 nm L&S

21: 53: 07



10 nm isolated line

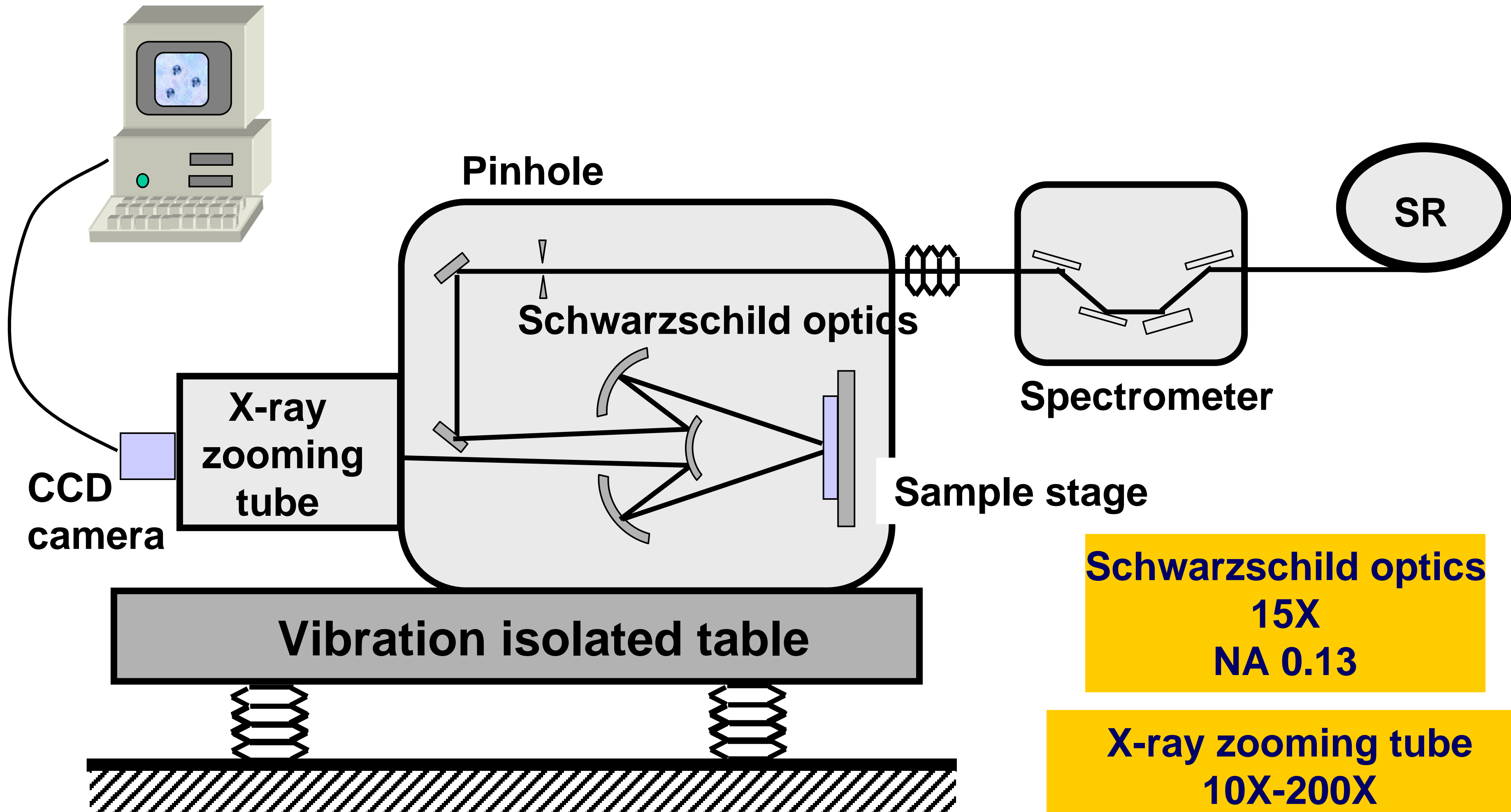
Development of Mirau interferometer



Specification of optics

Reference mirror Mo/Si
3nm positioning stage
Half mirror
Apperture: 15 mm square
Flatness: 1nm
R & T: 1:1 > 30%

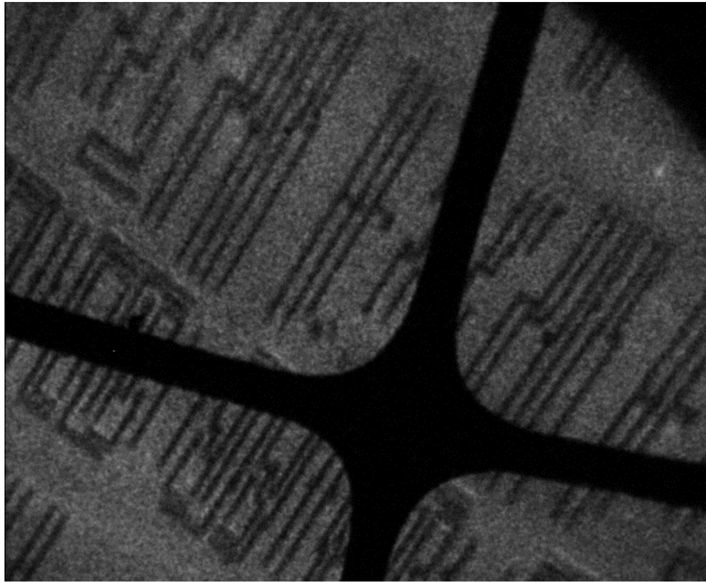
EUV Microscope (NTT Super-ALIS SBL8)



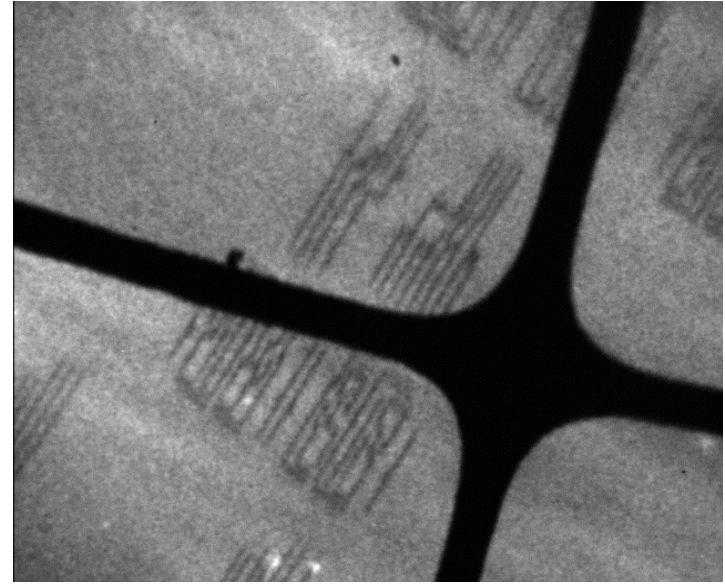
Schwarzschild optics
15X
NA 0.13

X-ray zooming tube
10X-200X
CsI photo cathode
Spatial resolution 0.5μm

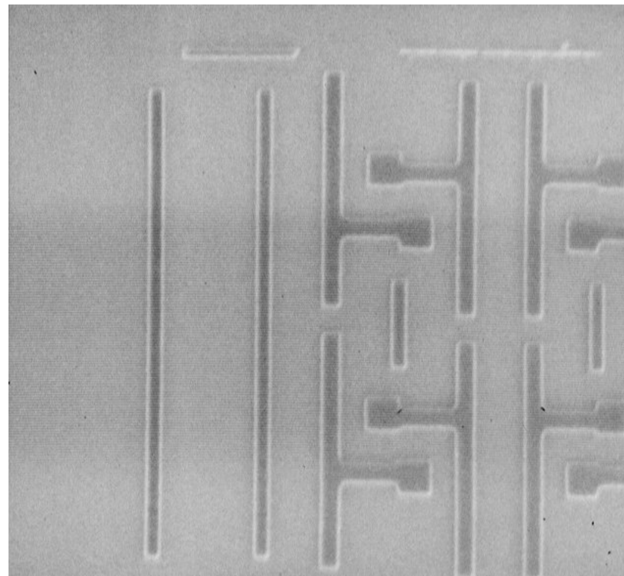
Device Pattern Inspection (TaBN mask)



350 nm on mask
(70 nm on wafer)



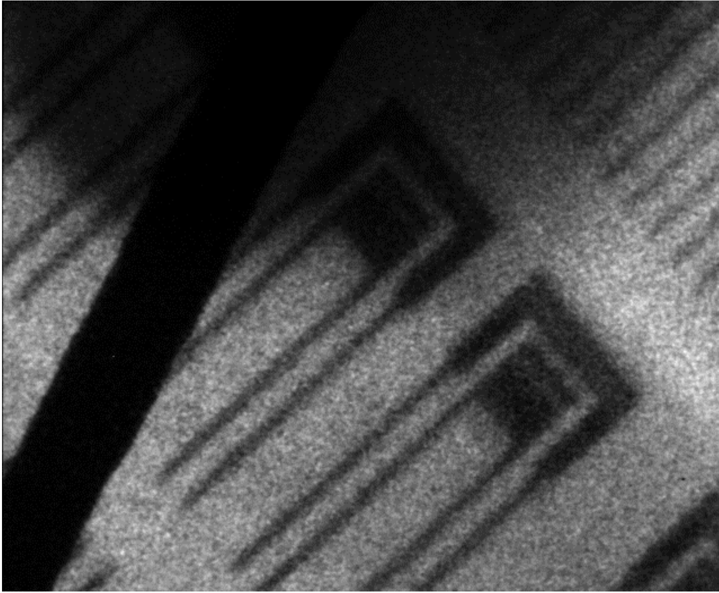
250 nm on mask
(50 nm on wafer)



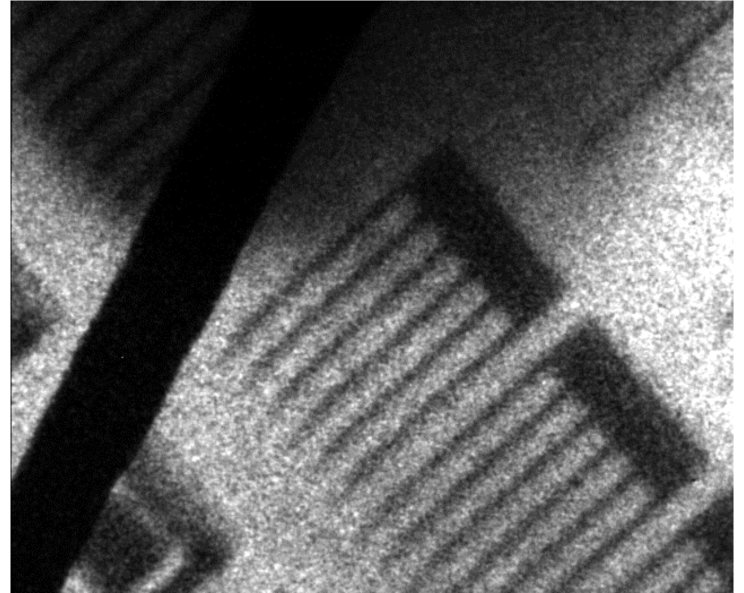
50 nm node mask can be observed by EUVM.

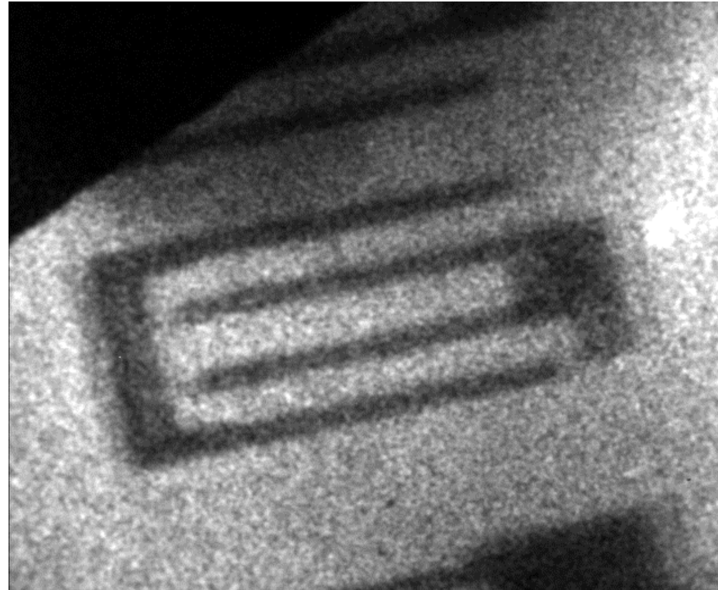
Device pattern mask was provide of PANASONIC

Device Pattern Inspection (70 nm node TaBN mask)



550X





1000X

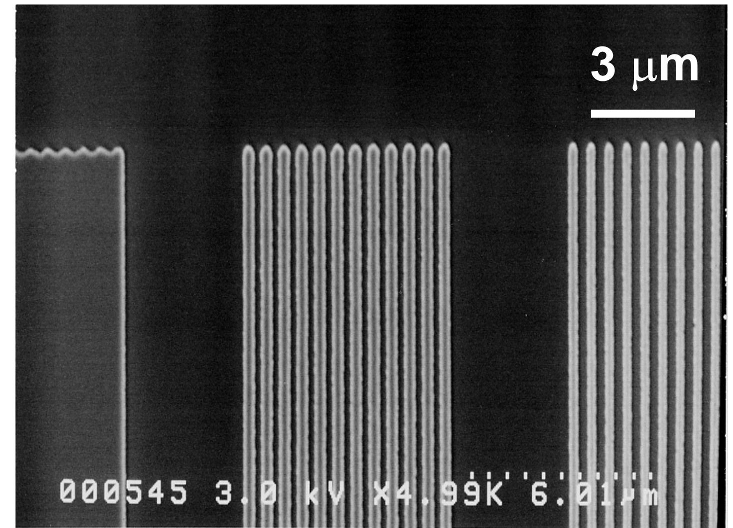
Defect Inspection (1)

350 nm L
250 nm S

300 nm L
300 nm S

3 μm

400 nm L
200 nm S



400 nm L
200 nm S

350 nm L
250 nm S

300 nm L
300 nm S

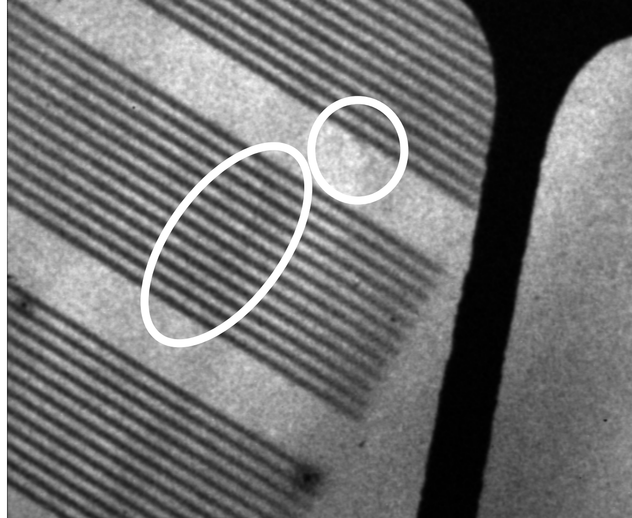
EUVM image

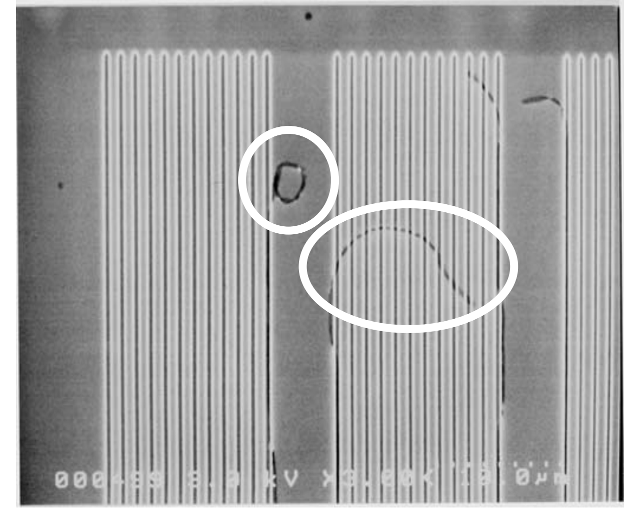
SEM image

Defect Inspection (2)

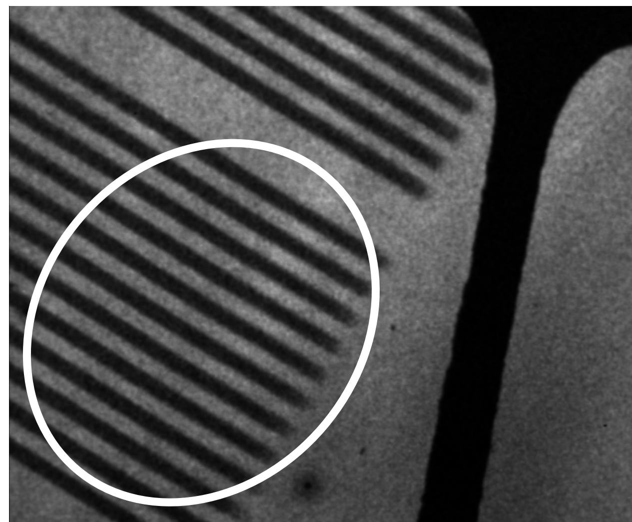
TaBN Mask

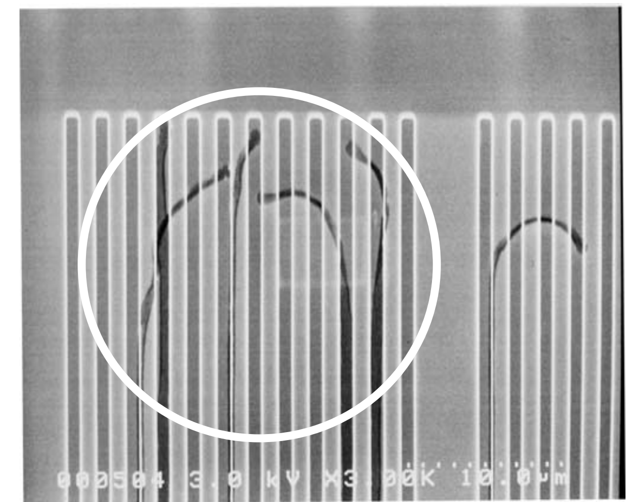
475 nm L&S





1000 nm L&S

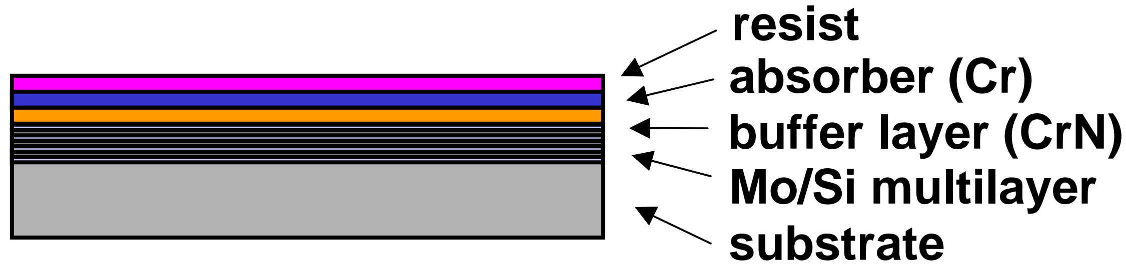




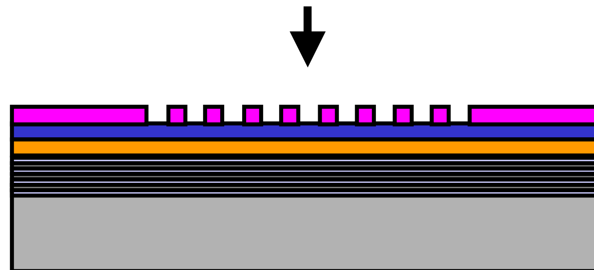
EUVM image

SEM image

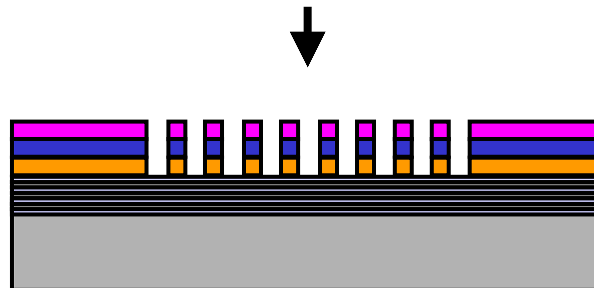
Mask Process



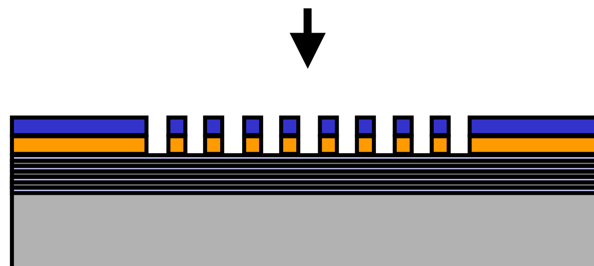
Lithography

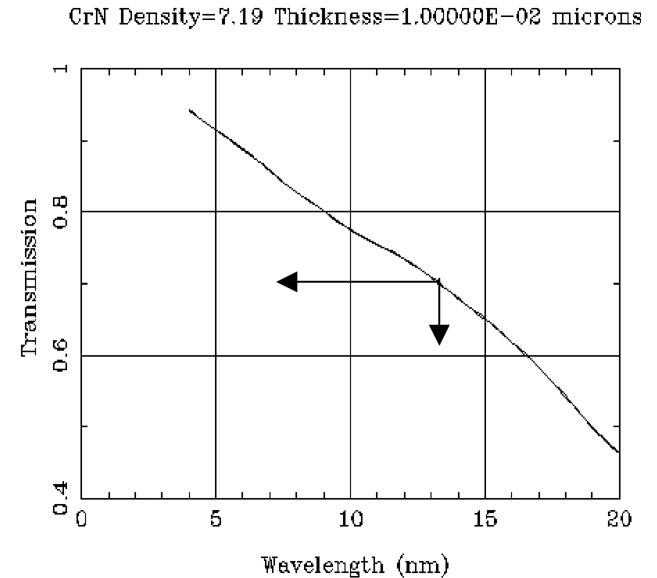


Wet etching



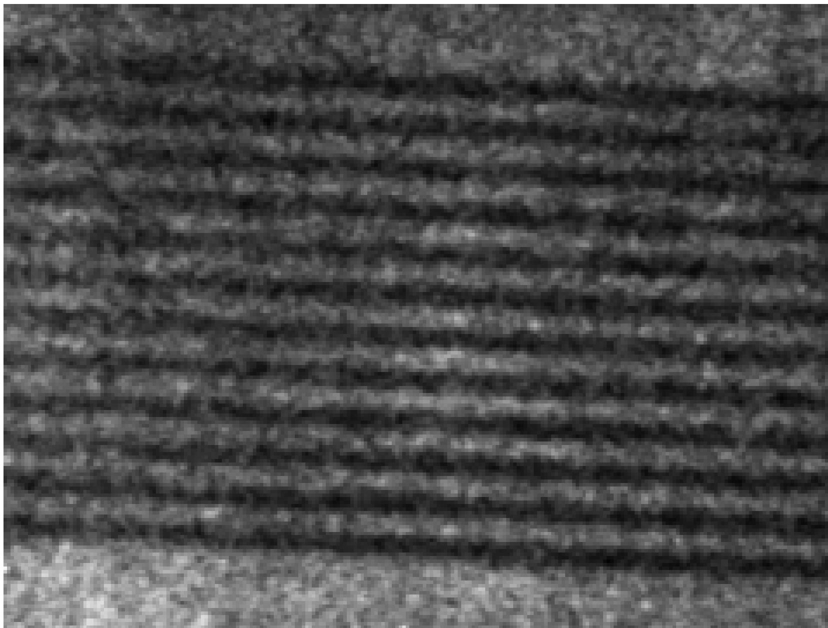
Resist remove



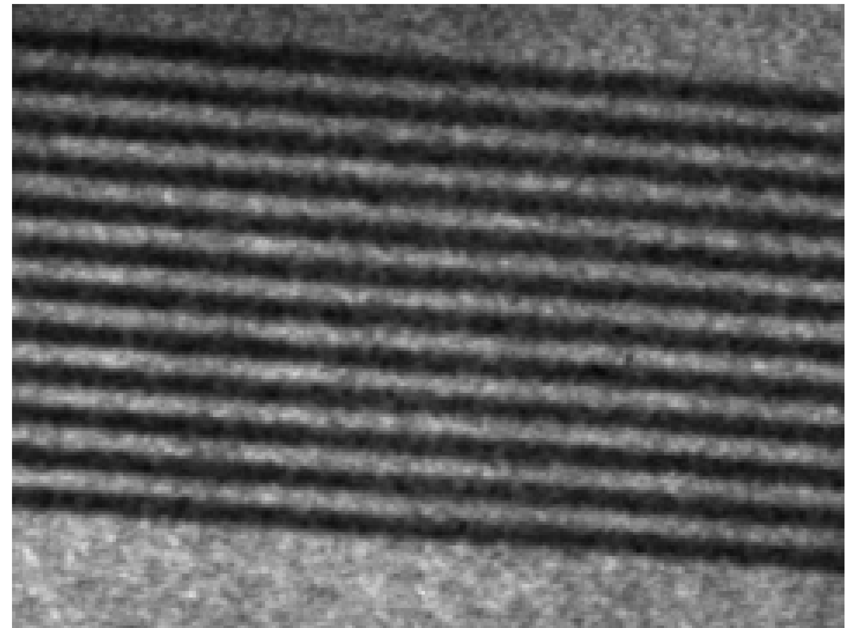


Transmittance of CrN in the thickness of 10nm is 70%. If the CrN film could not remove, theMo/Si reflectivity become to be half of it.

Comparison pattern resolution between Cr and TABN absorber pattern

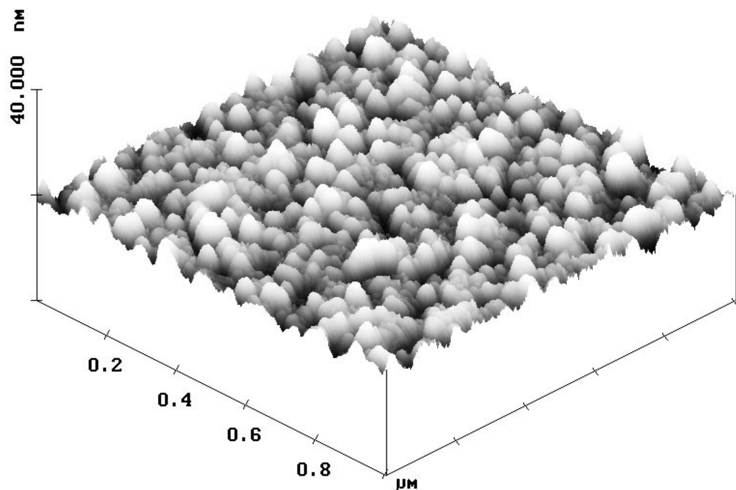


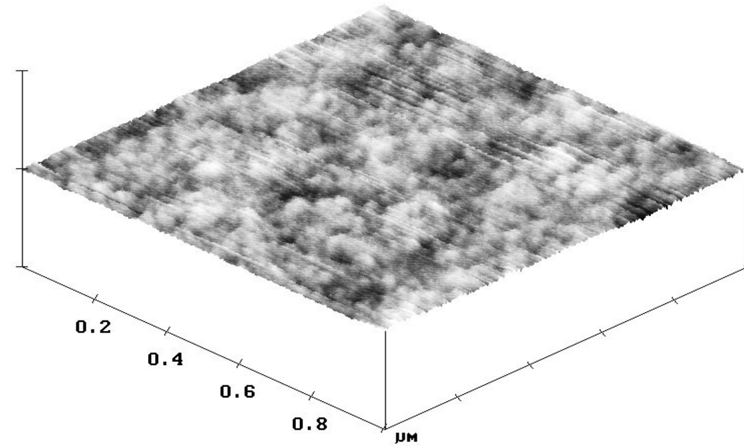
(a) Cr absorber pattern



(b) TaBN absorber pattern

Surface roughness of Cr and TaBN absorber layer





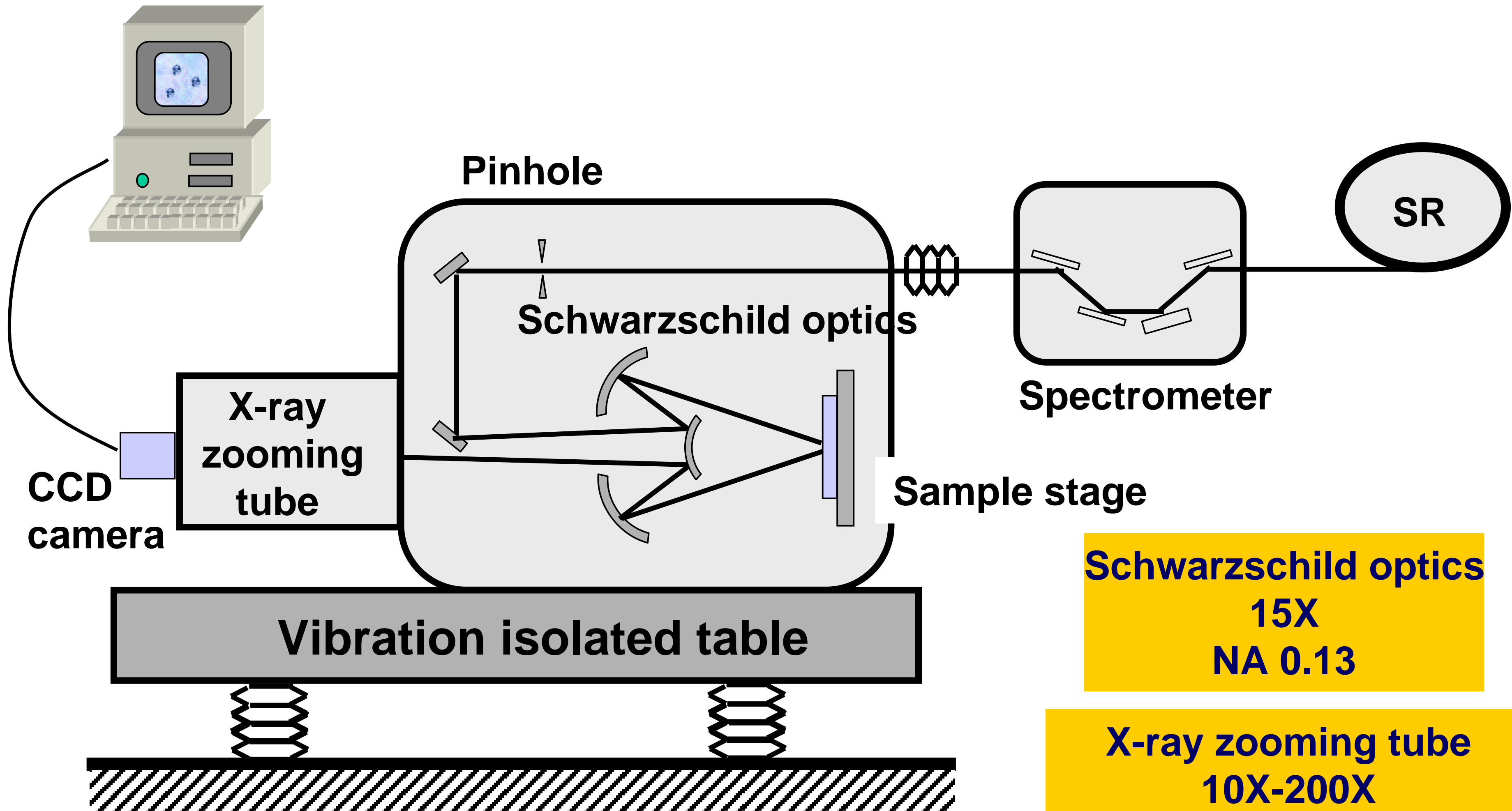
Cr

TaBN

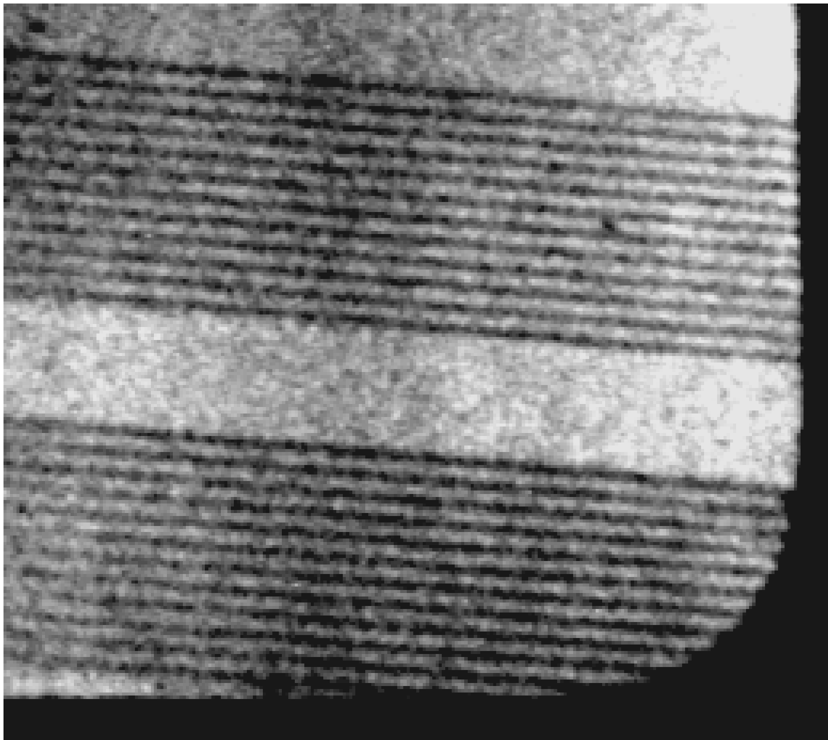
R=1.275 nm RMS

R=0.313 nm RMS

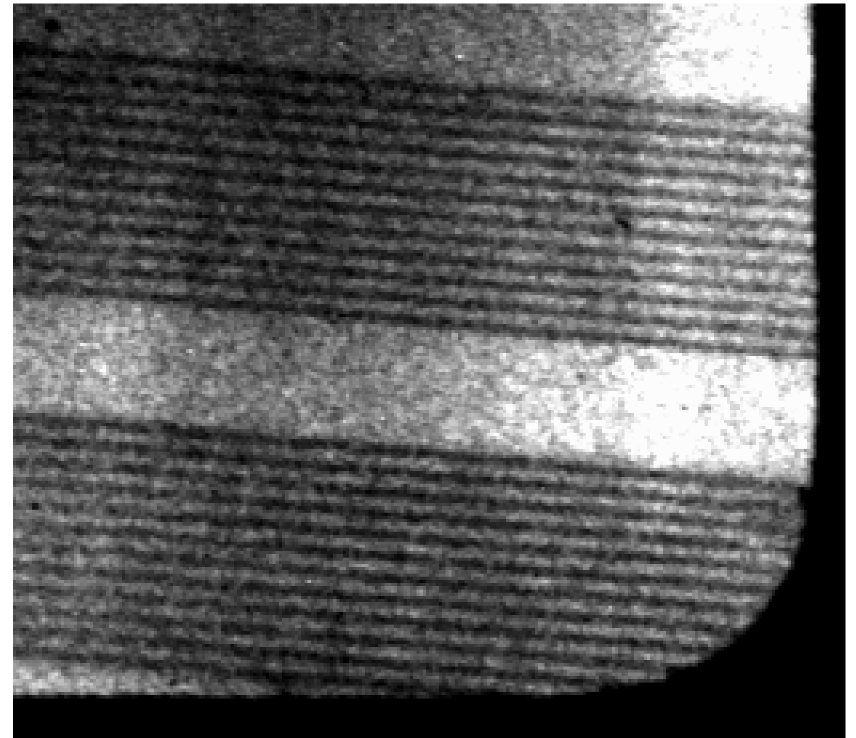
EUV Microscope (NTT Super-ALIS SBL8)



Comparison pattern resolution using white light and monochromatic light（ 1 ）



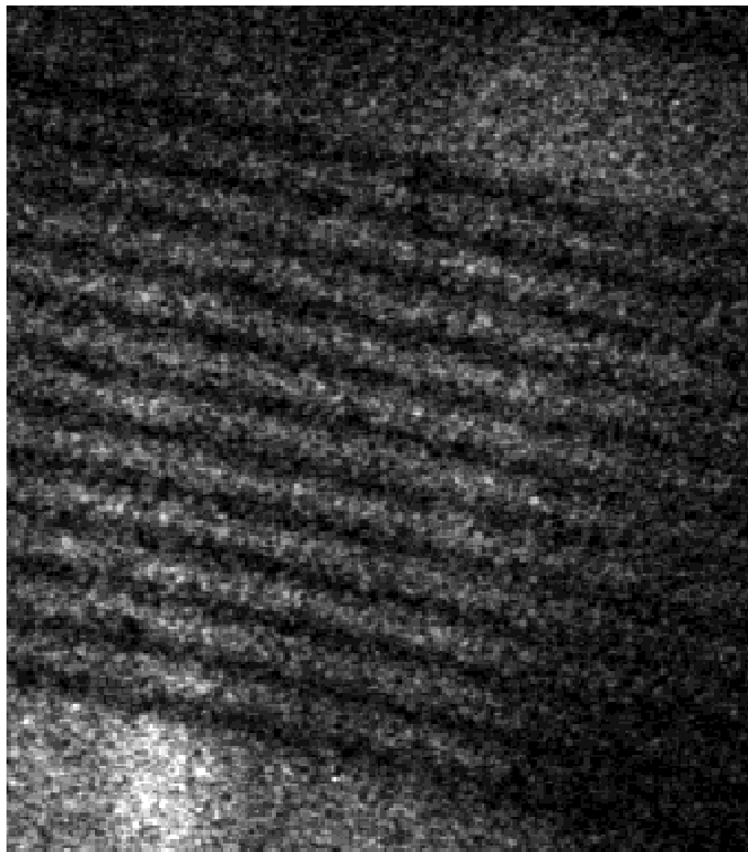
(a) White light



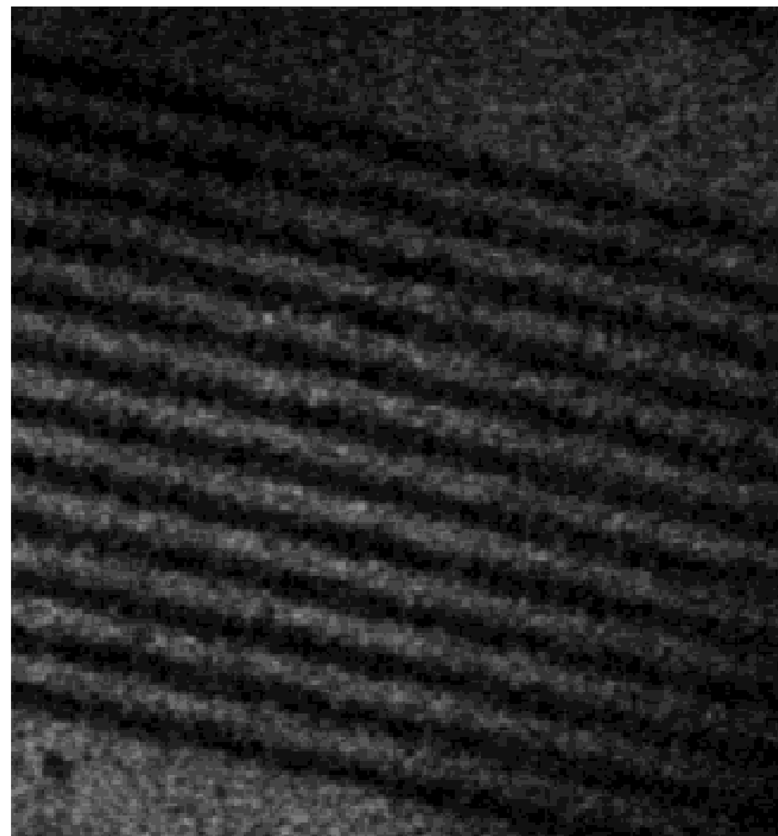
(b) Monochromatic light

Comparison pattern resolution using white light and monochromatic light（２）

Cr absorber　125 nm L&S



White light



13.5nm

Conclusion

(1) A new actinic mask inspection system has been developed, and simulations were carried out its imaging performance.
(2) Preliminary experiments using the EUV microscope developed at NTT have shown that it can resolve 250-nm-wide (on mask).
(3) Furthermore, the type of absorber material used in mask was found to have some effect on contrast on mask images.
(4) Pattern resolution for Cr and TaBN absorber layers are compared. Longer wavelengths should be completely eliminated in order to obtain a high resolution in pattern replication.
(5) These results demonstrate that an actinic inspection system is a powerful and useful tool for evaluating mask fabrication processes for EUVL.