Analysis of carbon contamination on EUV mask using CSM/ ICS

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HANYANG UNIVERSITY

Outline

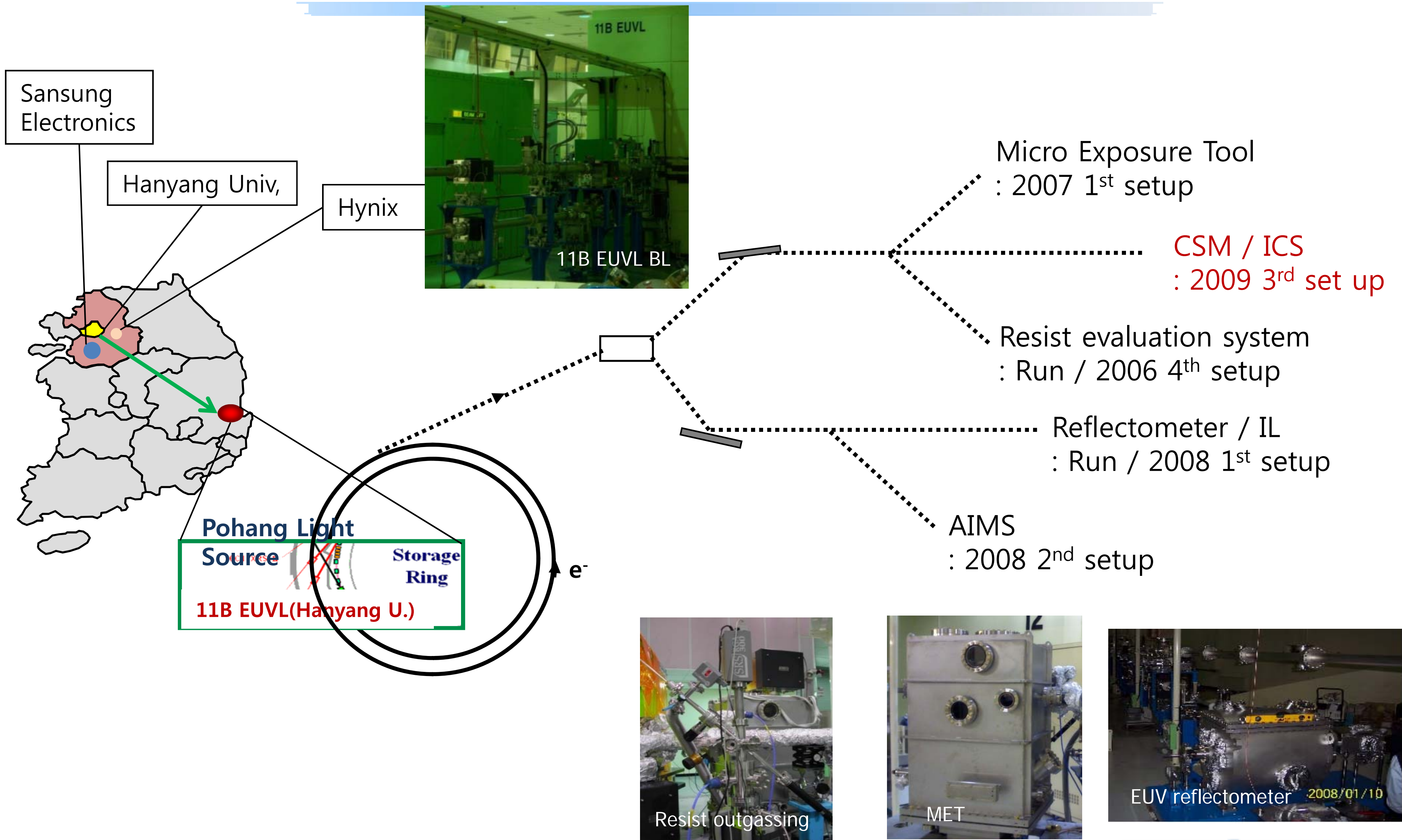
- **EUVL test bed**
  - EUVL critical issue
  - EUVL test bed
- **Mask Contamination/Inspection System**
  - Concept of system
  - Optical design
  - CSM image
- **Carbon contamination analysis**
  - EUV reflectivity change
  - Influence of carbon contamination
- **Summary**

EUVL Critical issue - development target

2007	2008	2009
1. Reliable high power source & collector module	1. Long-term source operation with 100W at IF and 5MJ/day	1. Mask yield and defect inspection/review infra structure
2. Resist met RLS simultaneously	2. Defect free masks through lifecycle & inspection/ review infrastructure	2. Long term reliable source operation with 200W at IF
3. Availability of defect free mask	3. Resist met RLS simultaneously	3. Resist met RLS simultaneously
4. Reticle protection during storage, handling and use	4. Reticle protection during storage, handling and use	4. EUVL manufacturing integration
5. Protection/ illuminator optics and mask lifetime	5. Protection/ illuminator optics and mask lifetime	

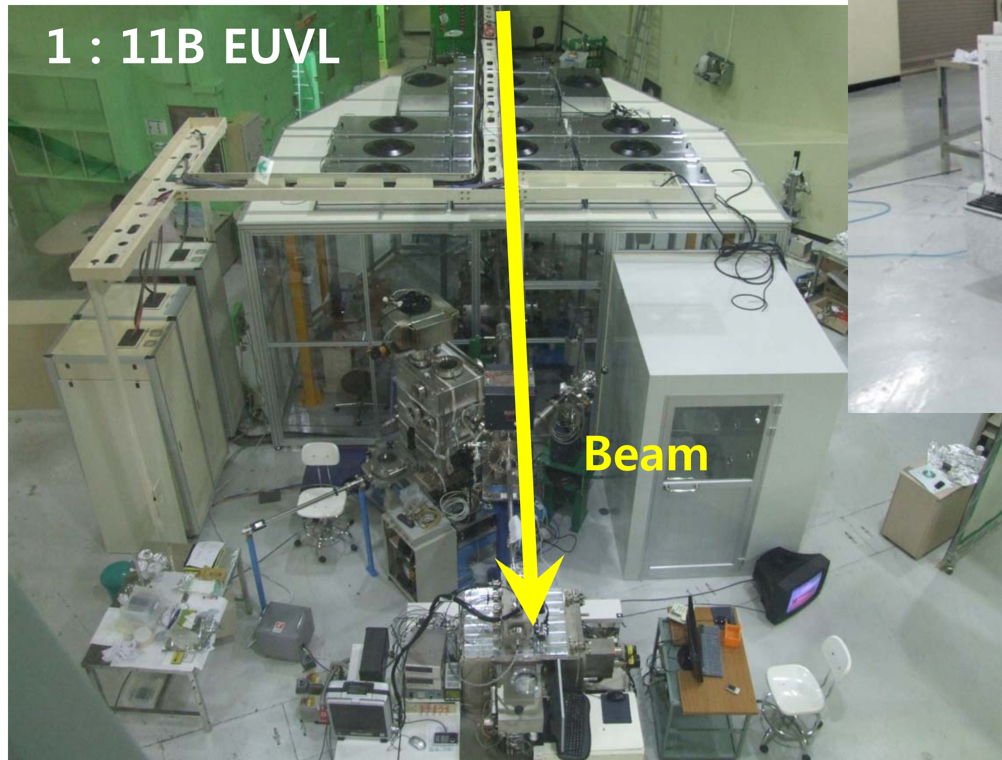
EUV symposium 2009

EUVL test bed - Infrastructure



EUVL test bed

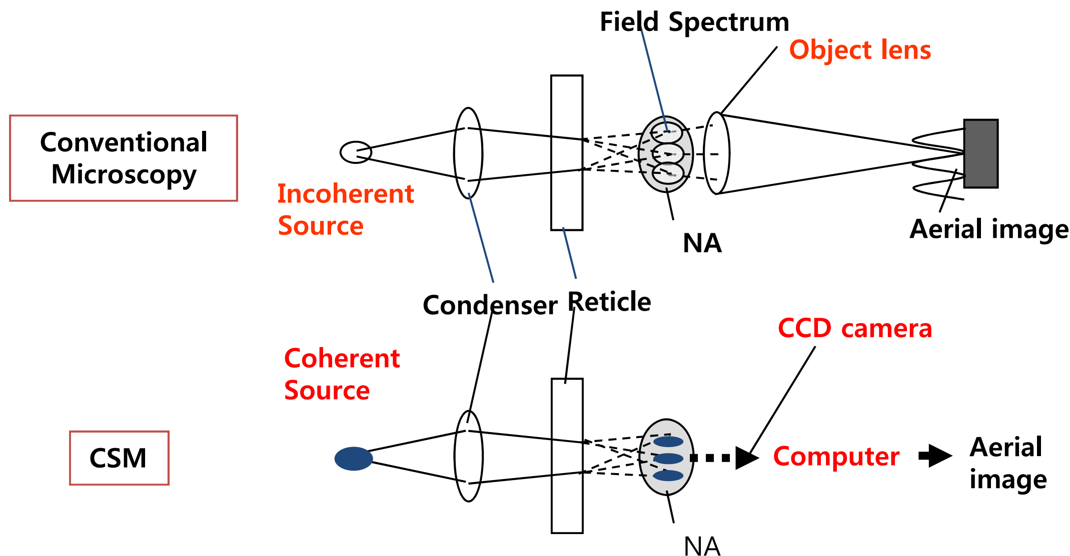
1. 11B EUVL beamline
2. EUV CSM / ICS system
   -Coherent Scattering Microscopy/
   In-situ Contamination System



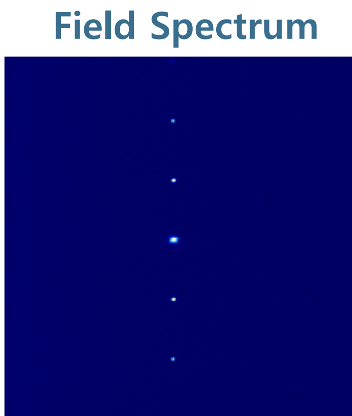
EUV mask analysis
- Actinic CD measurement
- H-V bias measurement

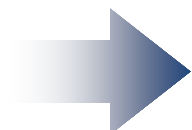
In-situ monitoring of mask contamination

Introduction of CSM



Field Spectrum



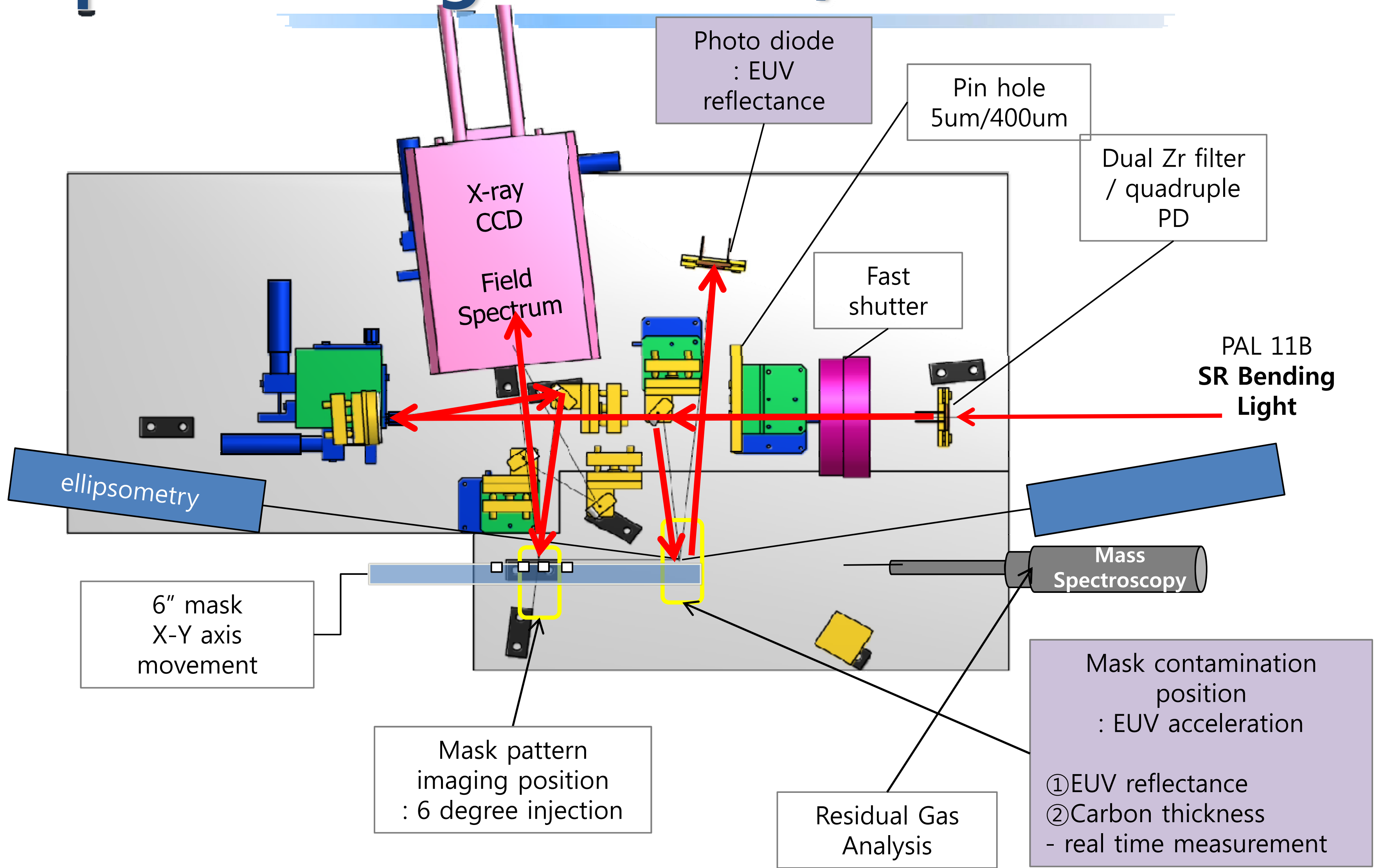


Reconstructed Aerial Image

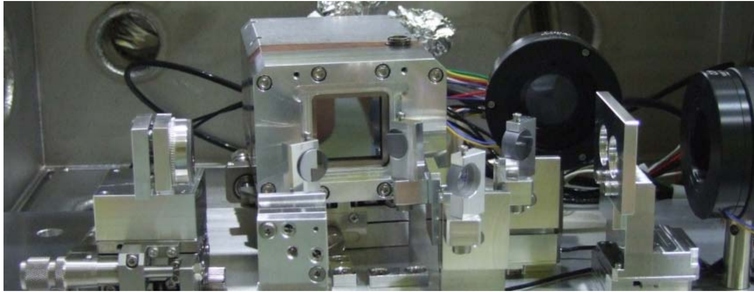
Field spectrum
→ mask image reconstruction
→ wafer aerial image
- actinic CD measurement, mask defect inspection

Source : EUV symposium 2008 Donggun Lee., et al

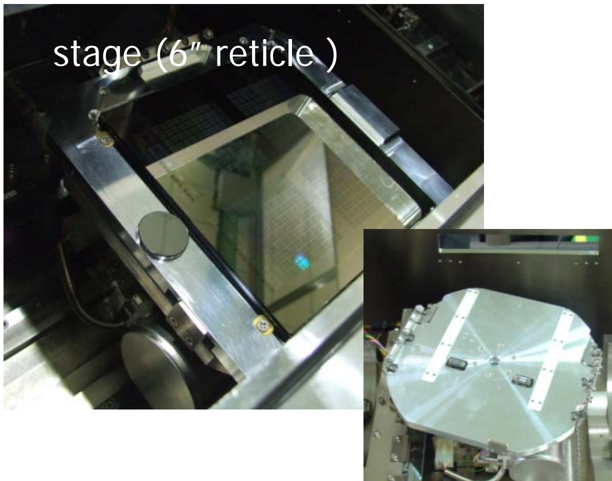
Optical design of CSM/ICS

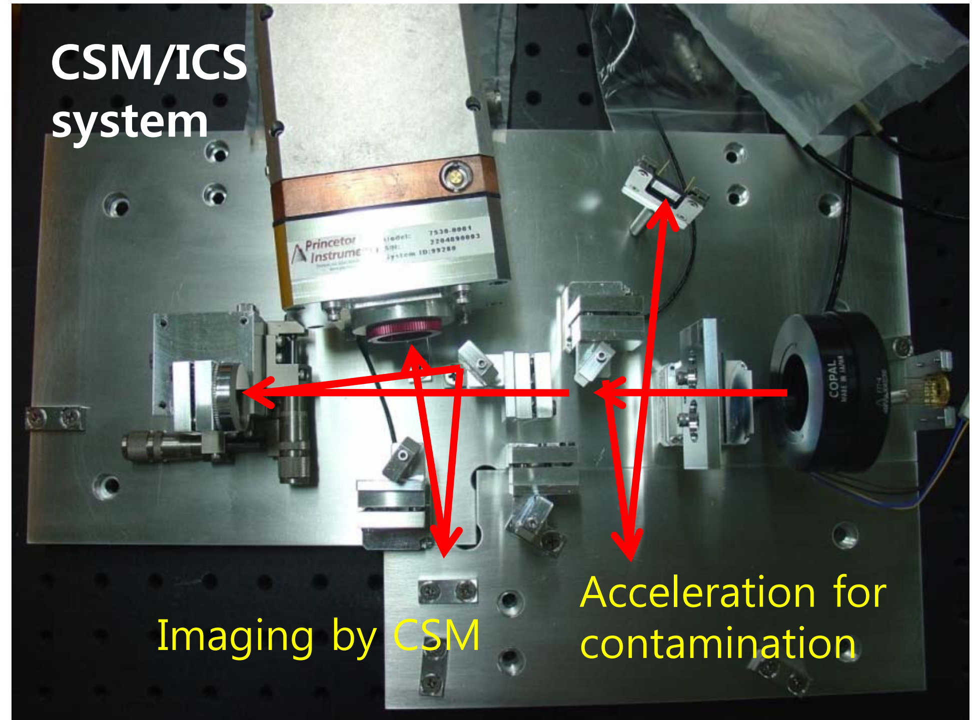


Optical design of CSM/ICS



X-ray CCD camera
: Pixel - 2048 X 2048 imaging array
Pixel size – 13.5 X 13.5 um^2
Imaging area – 27.6 X 27.6 mm^2
Vacuum compatible



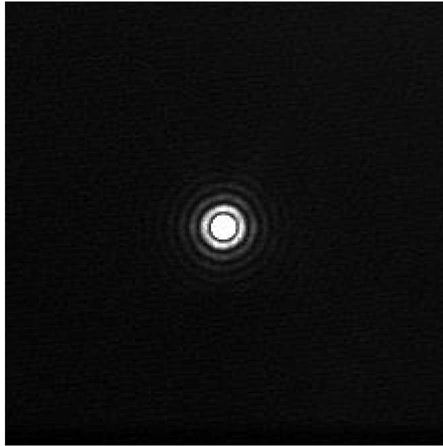


- **Enable to test imaging performance of EUVL mask with carbon contamination**

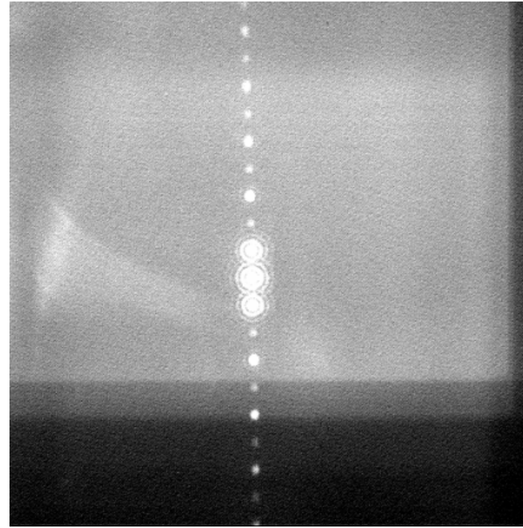
  : In-situ imaging

  (C contamination & image for inspection)

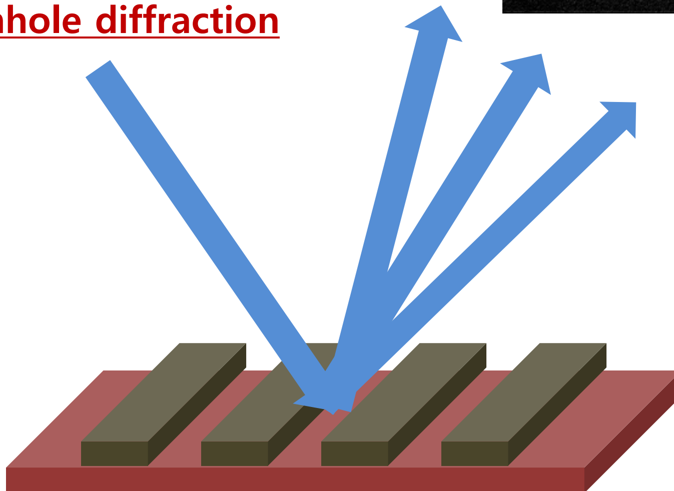
CSM image



5 μ m pinhole diffraction

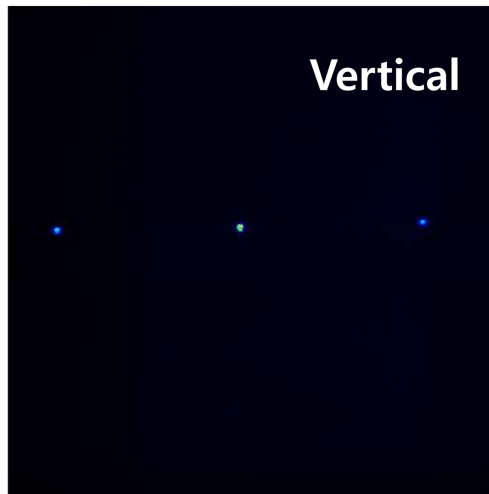


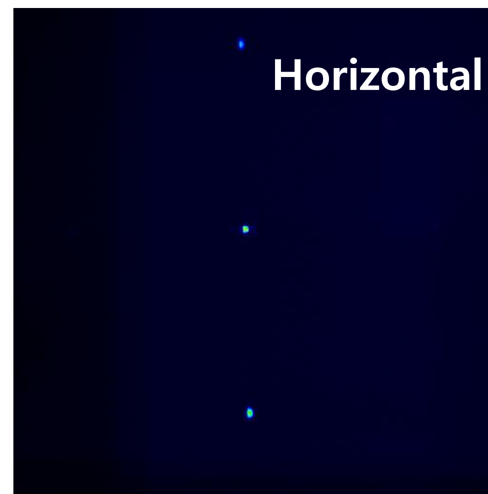
10th order diffraction
125nmL/S (wafer scale)



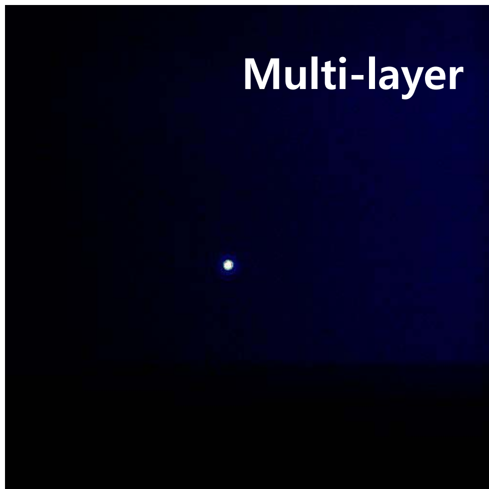
12.5nm (wafer scale) node
EUV mask CD & H-V bias
measurement possible!
$m\lambda = d\sin\theta$
Distance between pattern $\propto 1/d$

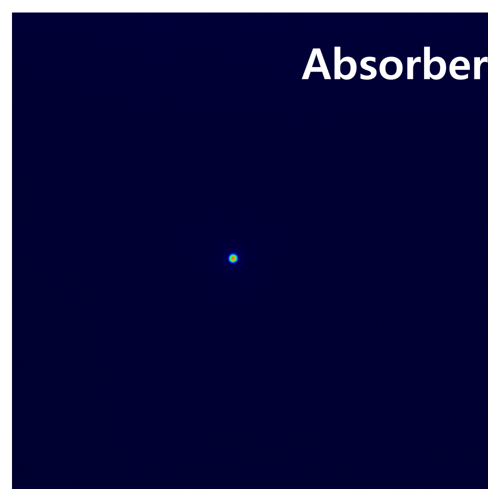
CSM image





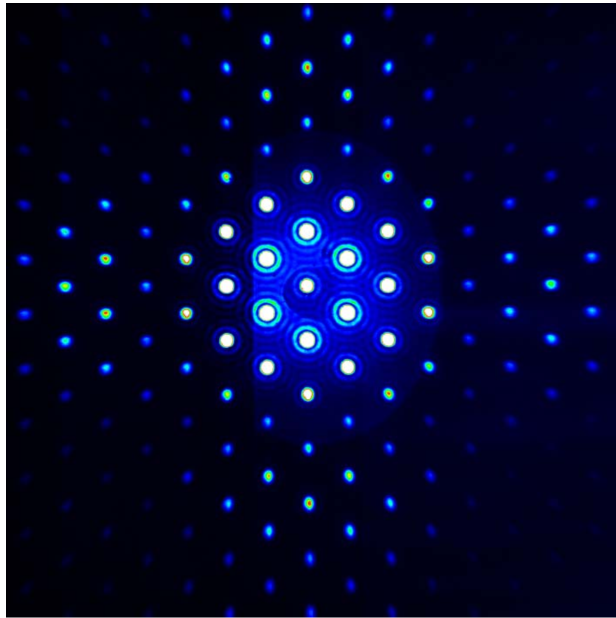
17.5nm L/S pattern (wafer scale)

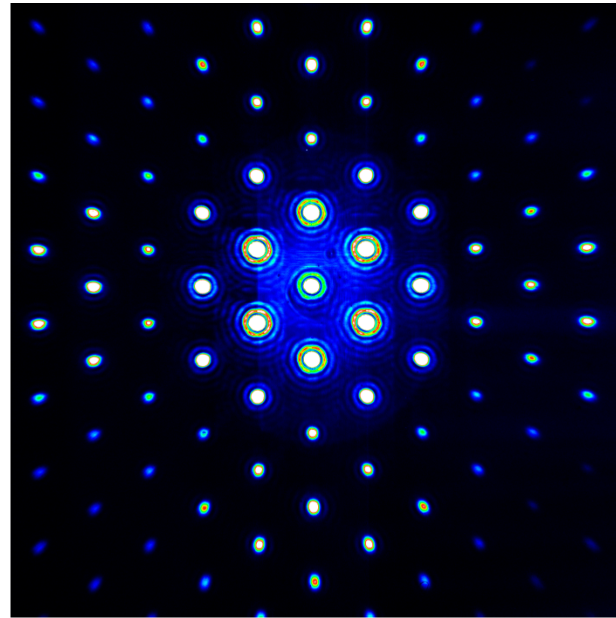


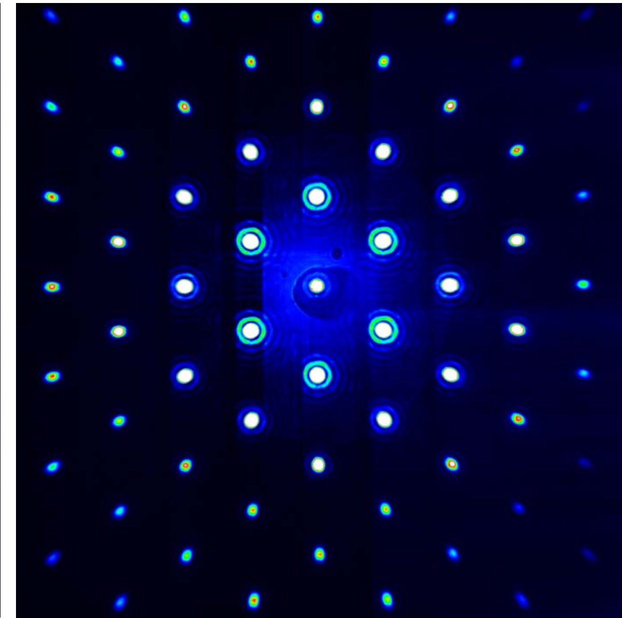


CSM image

Contact hole diffraction pattern

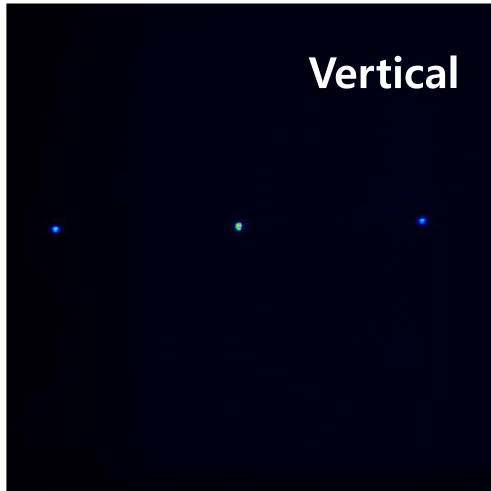


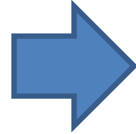


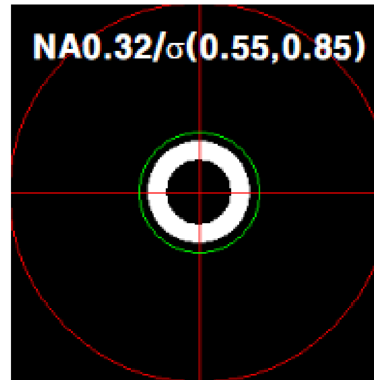


46nm node　　34nm node　　28nm node

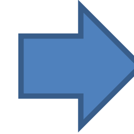
CD repeatability

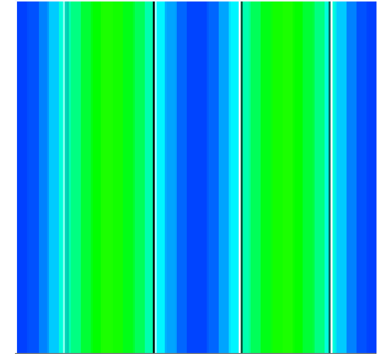




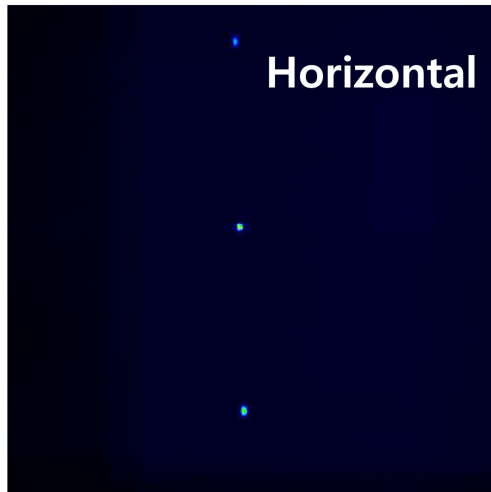


Illuminator Kernel

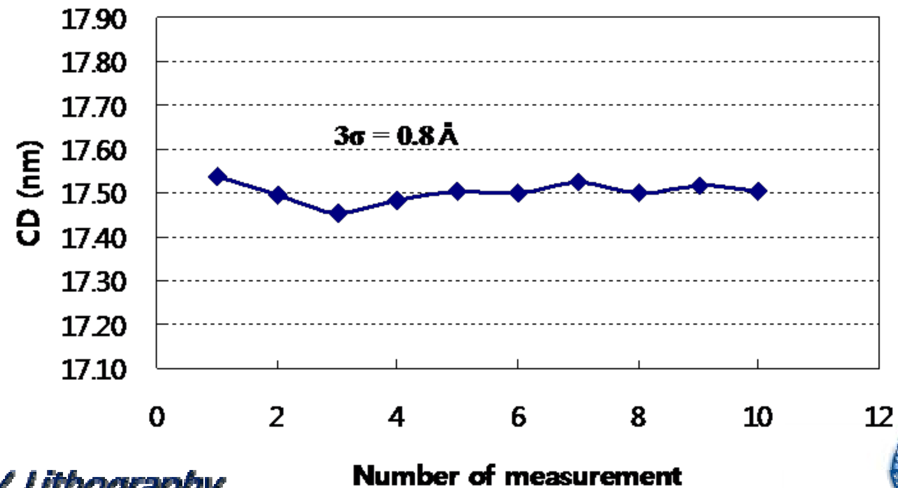




Aerial image

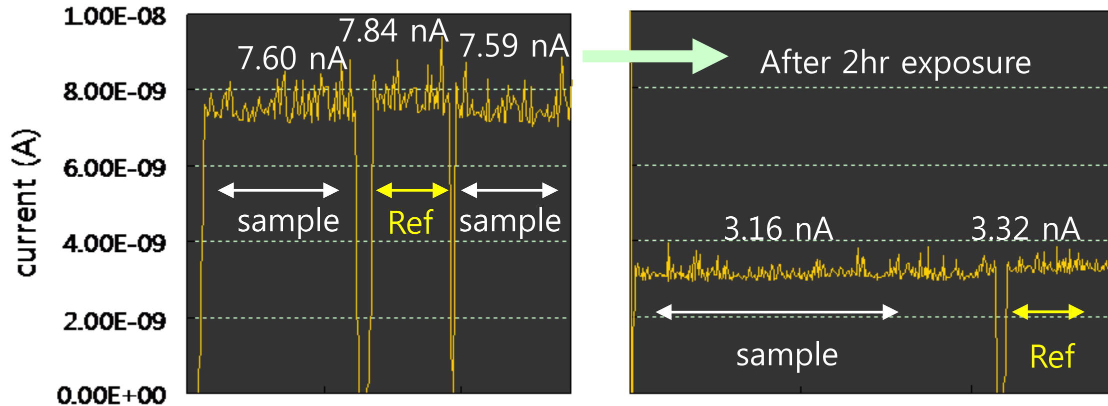


CD measurement repeatability

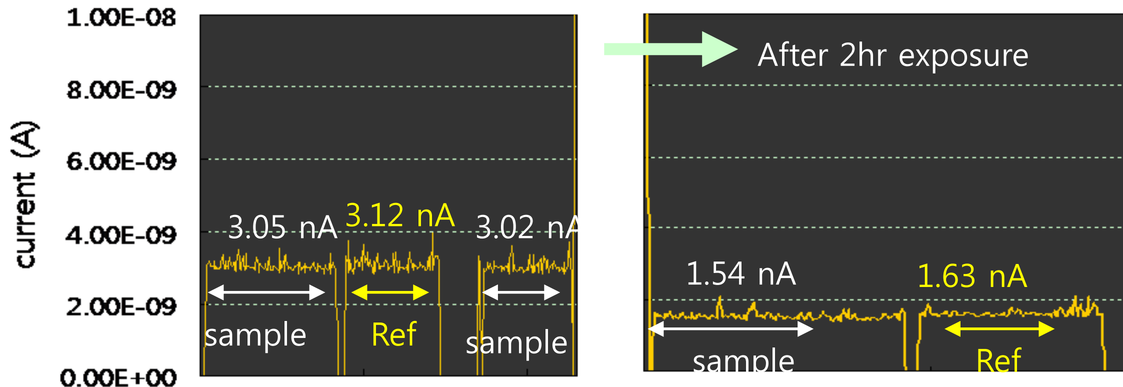


EUV reflectivity change

Photo diode current for Acceleration test



Blank mask (A): 1.86% Reflectivity Drop

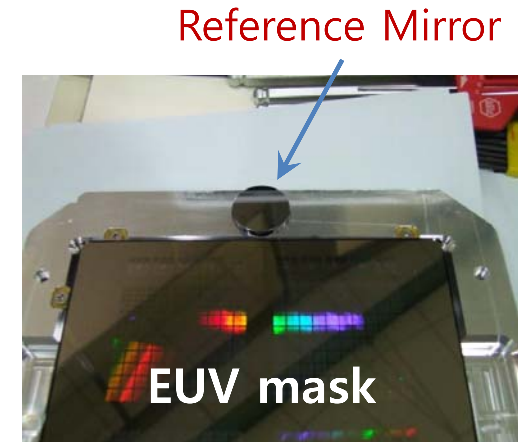


Blank mask (B): 2.92% Reflectivity Drop

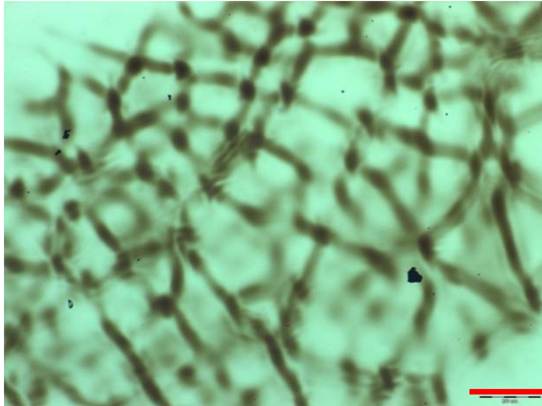
Use relative reflectance change between Ref and evaluation mask

EUV mask acceleration test (2hours) : Change of EUV reflectance

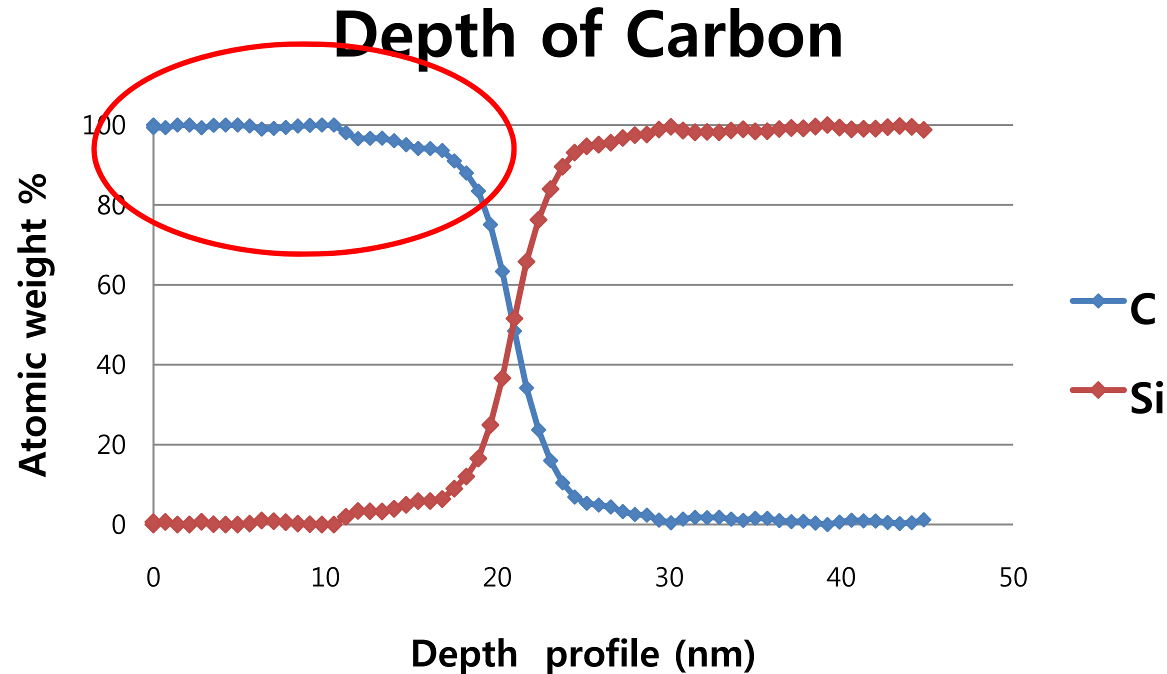
Reference Mirror



Carbon contamination analysis



Optical microscope image of carbon after 2hr acceleration

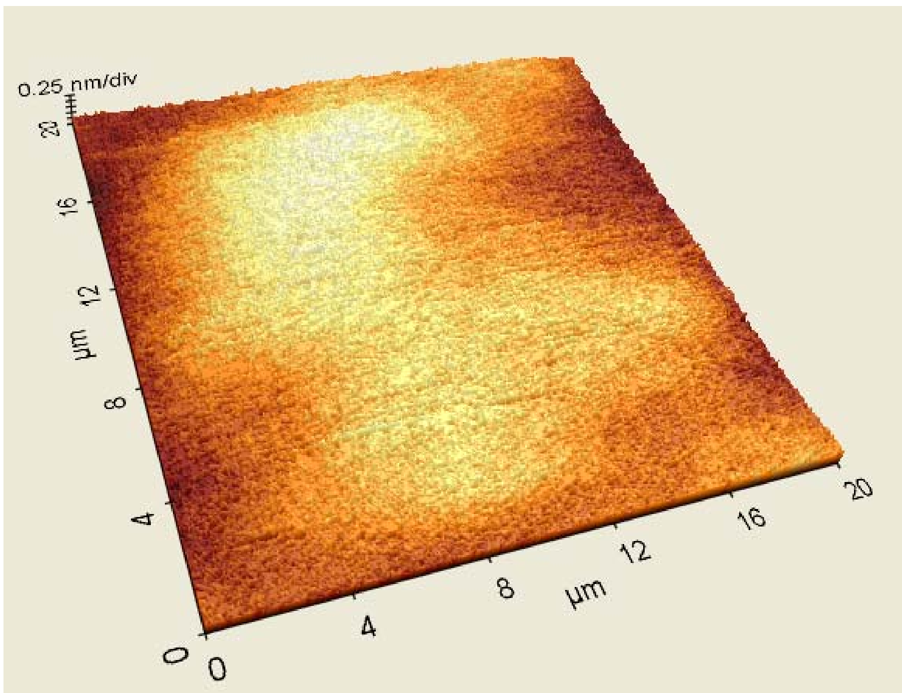


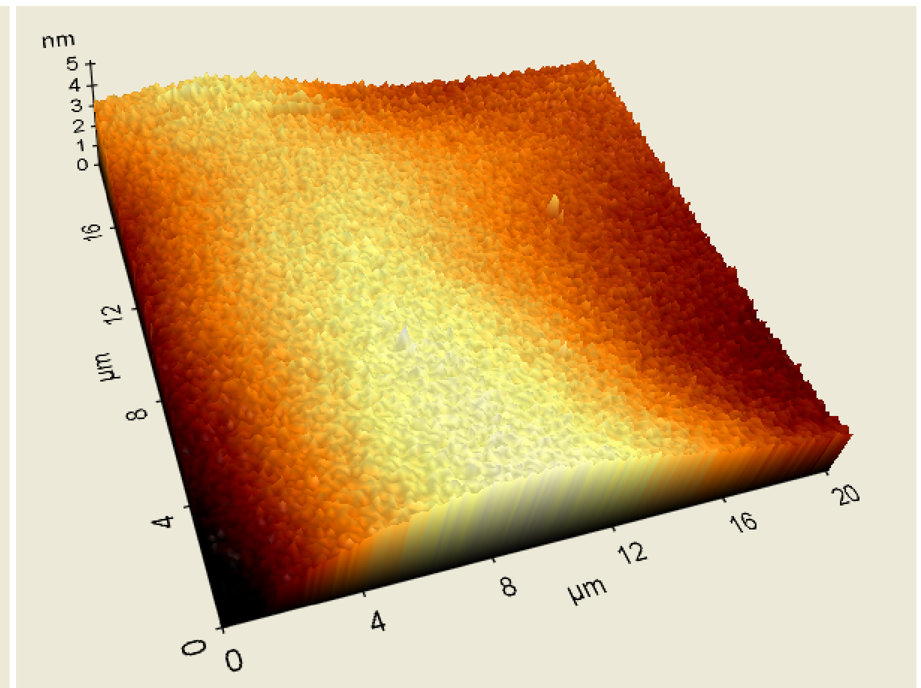
Atomic weight % of Carbon and Silicon analyzed by AES

Beam size: 1.5mm diameter
64 step, 0.7nm per 1step

Influence of carbon contamination

AFM image of Carbon contamination

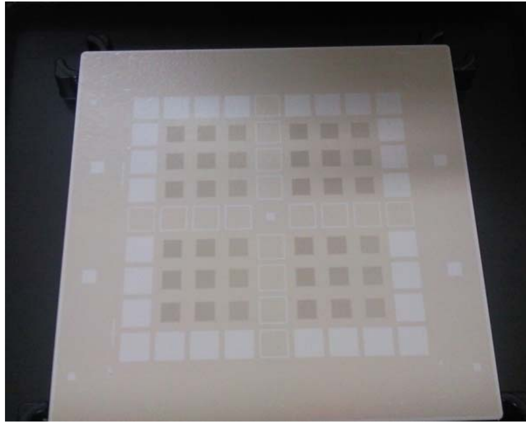




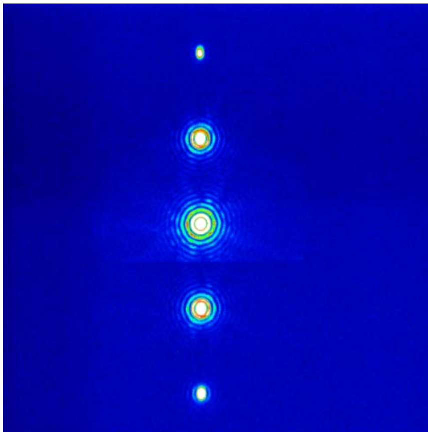
RMS Roughness
Before : 0.20nm

RMS Roughness
After 2hr: 0.74nm

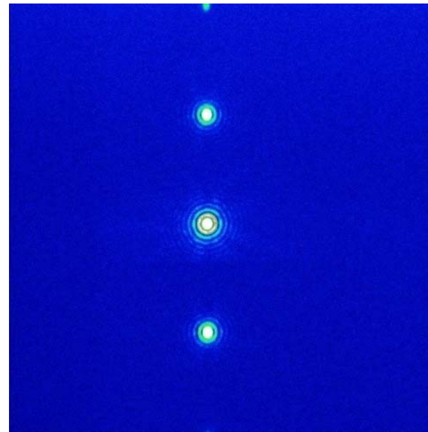
CSM image for evaluation



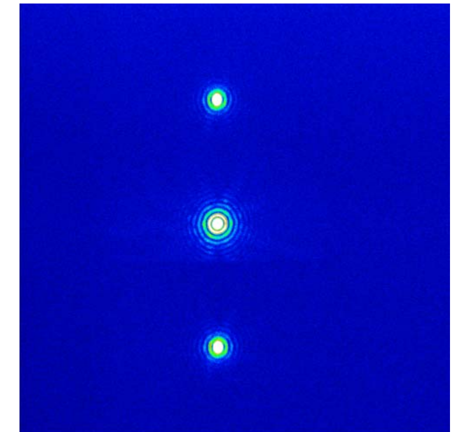
Test mask for evaluation of carbon contamination effect on imaging



32nm L/S
(wafer scale)



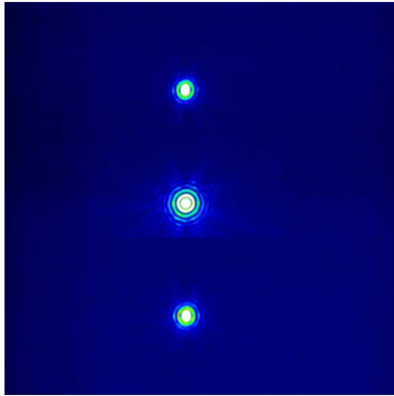
25nm L/S
(wafer scale)



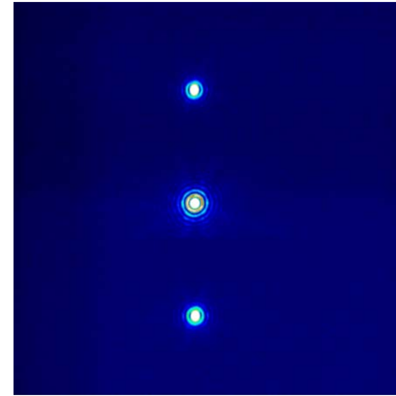
22nm L/S
(wafer scale)

Contamination analysis using CSM

CSM diffraction pattern after acceleration



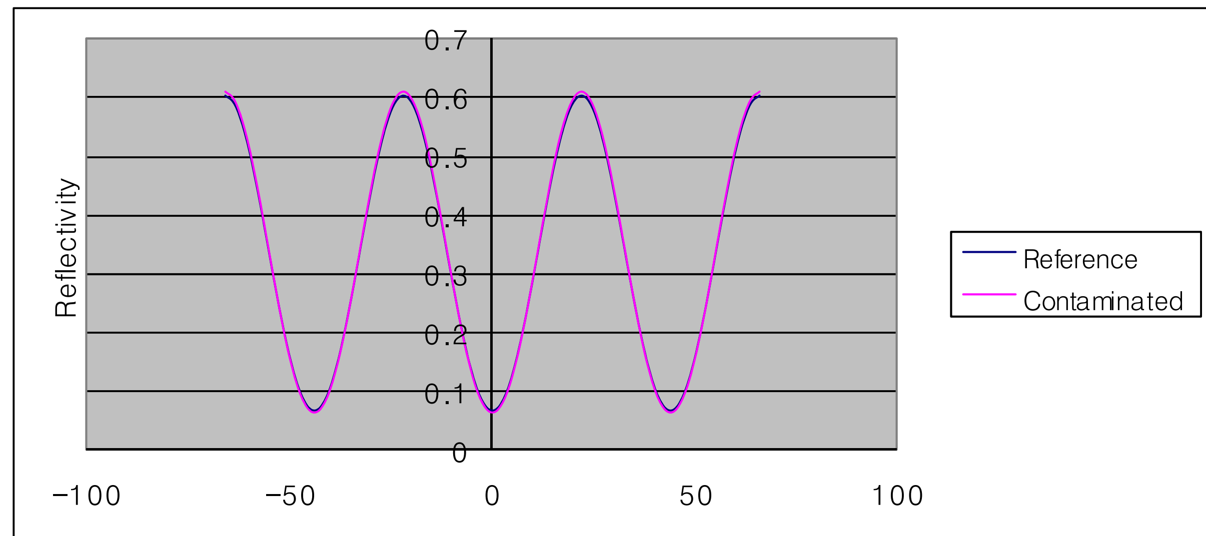
Before



2hr acceleration

CD measurement results (NA0.32, σ0.8)

	Reference	Contaminated
CD(nm)	22.47	22.31
Contrast	0.8034	0.81



Summary

- Coherent Scattering Microscopy/ In-situ Contamination System were constructed
  - 12.5nm node actinic CD measurement
  - 28nm node contact hole image reconstruction
  - CD repeatability < 1Å (3σ)
- We anticipate that CSM/ICS will help to evaluate and measure performance of EUV mask