Measurements of reflectance drop by contaminations on multilayer mirrors at NewSUBARU

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Research Sites

- Himeji (Univ. of Hyogo)
- Sagamihara (Nikon)
- Utsunomiya (Canon)

Research Laboratories

- **SR+Undulator "NewSUBARU" in Himeji (Univ. of Hyogo)**
  - high power irradiation (Undulator)
  - accelerating experiments
  - material screening
- **SR "Super-ALIS" in Atsugi (NTT)**
  - light intensity/dose dependency test
  - H_2O/C_xH_y partial pressure dependency test
  - cleaning test

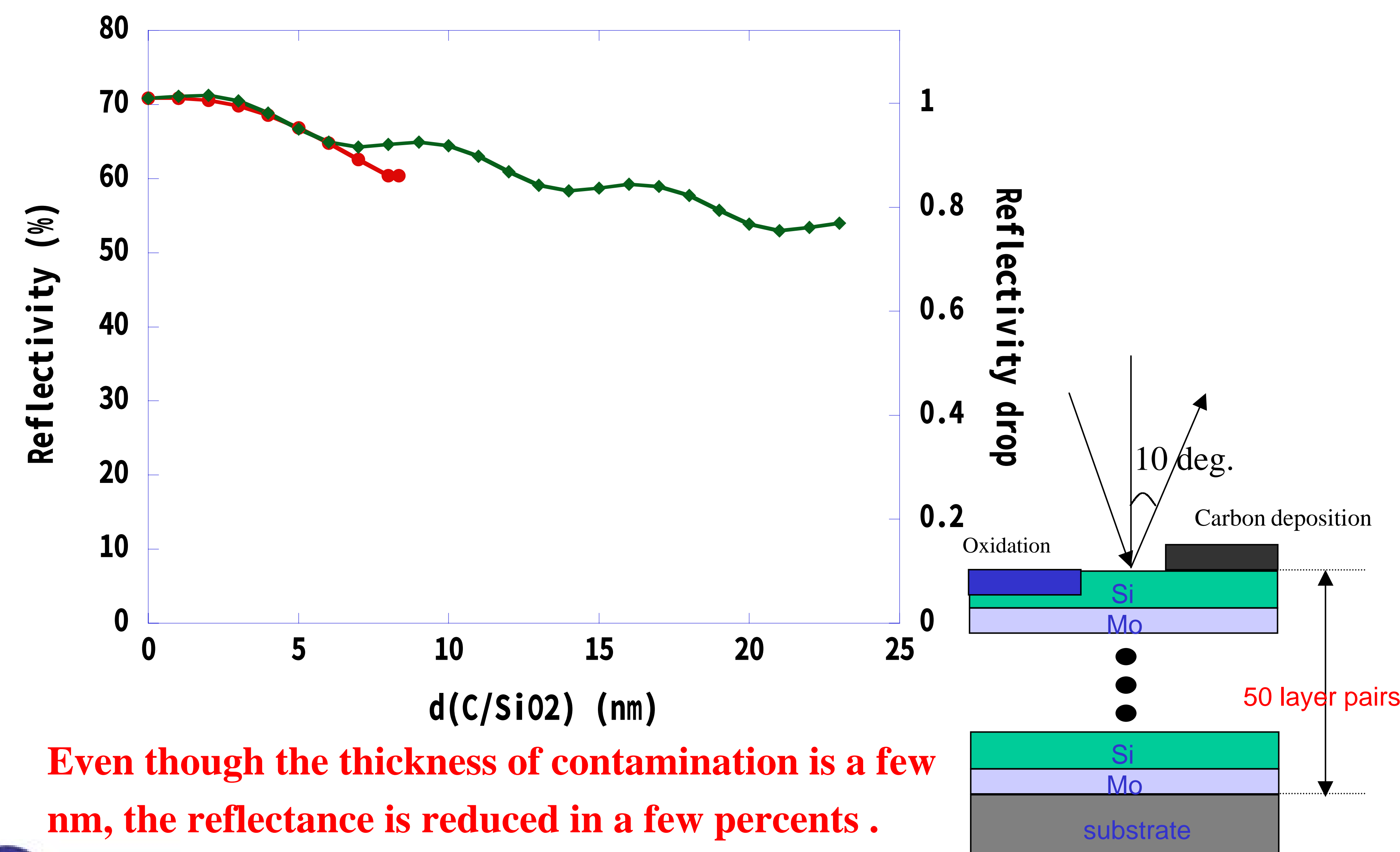
Background

- Mo/Si multilayer mirrors (MLMs) are used to constitute projection optics for EUV lithography (EUVL) system.
- Carbon deposition and/or oxidation are progressed during EUV exposure, which make reflectance drop.
- Mirrors whose reflectances are semi-permanently kept are needed.
- An accelerating test using high flux beam is needed to evaluate a reflectance drop in a short time.

Purpose

- **Developing an EUV irradiation and reflectance measurement system using high flux EUV source for *in-situ* measurement of reflectance drops depending on beam flux, atmosphere and capping layer.**
- **Attempting *in-situ* observation of contaminations at the surface of the sample.**

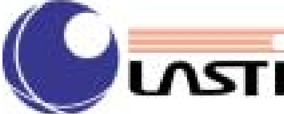
Calculated reflectance drop by carbon deposition or oxidation



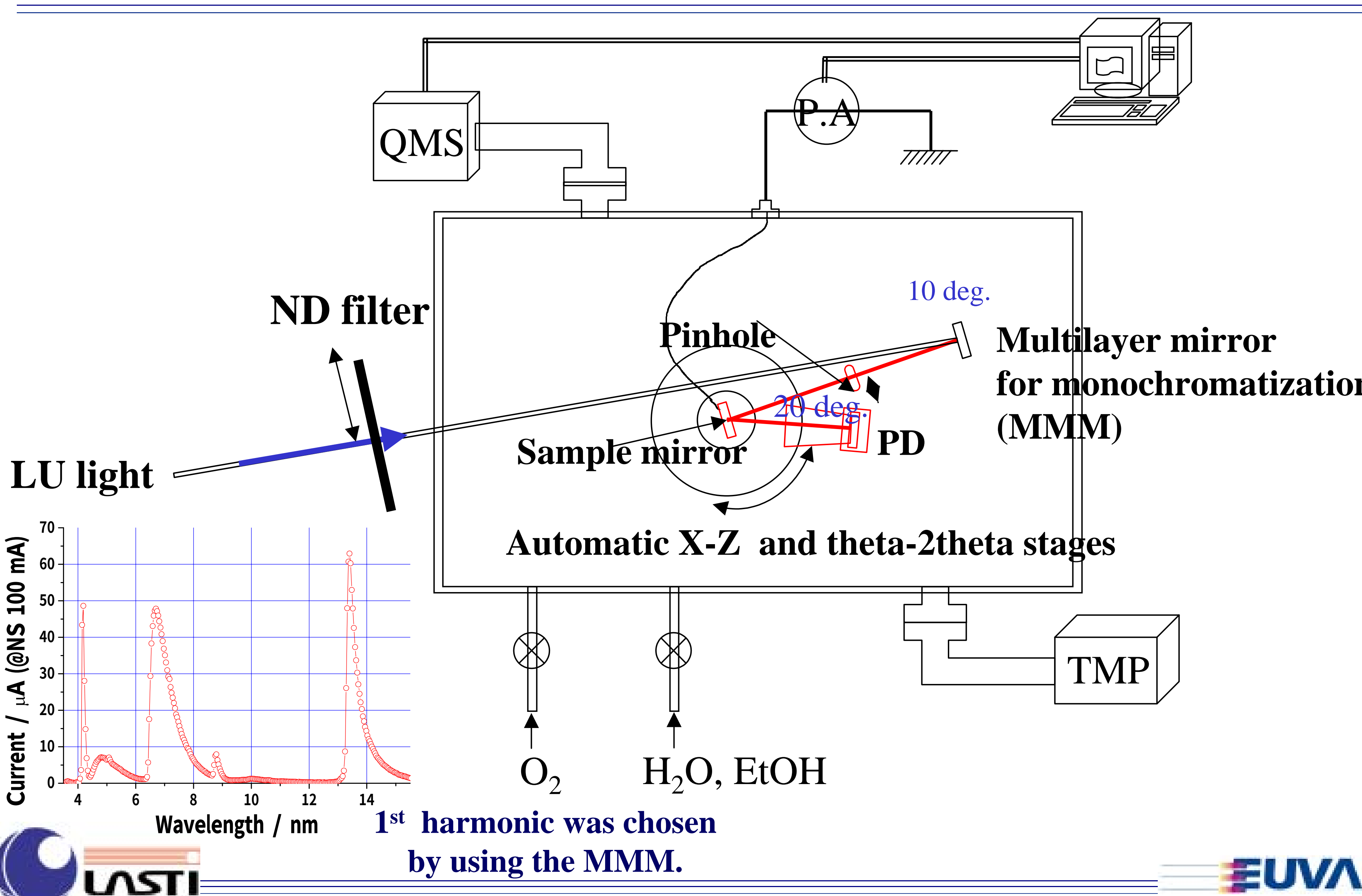
Even though the thickness of contamination is a few nm, the reflectance is reduced in a few percents .

Long Undulator beam line at NewSUBARU

Mirror / Grating (Monochromator section)

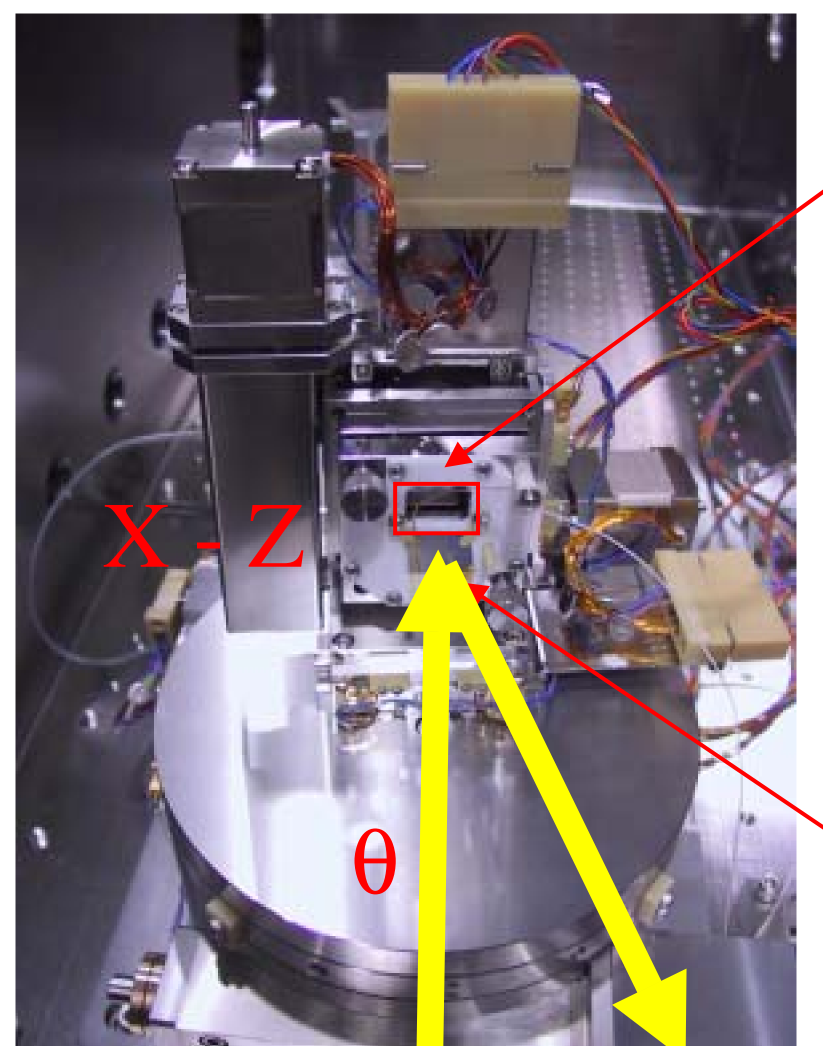


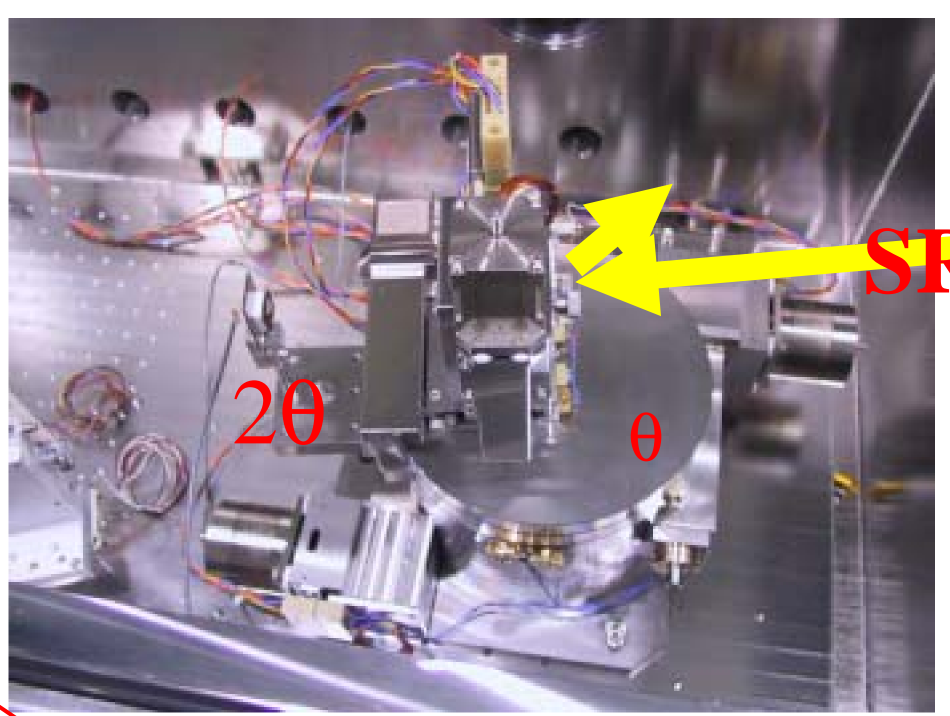
Experimental system



1st harmonic was chosen by using the MMM.

Automatic stages for sample positioning





Window

Sample

Irradiation atmosphere (H_2O introducing)

Only changed around M/e=18

Pressure (Pa)

4.5×10^{-5}

1.0×10^{-10}

1 55 200

Mass number (M/e)

Before introducing water vapor

1.3×10^{-3}

1 55 200

Mass number (M/e)

After introducing water vapor (1.3×10^{-3} Pa)

Mo/Si multilayer samples

Si-capped sample **Ru-capped sample**

Profile of irradiation beam

Intensity 500 mW/mm^2 +/– 10%
200 (V) x 250 (H) μm^2 area

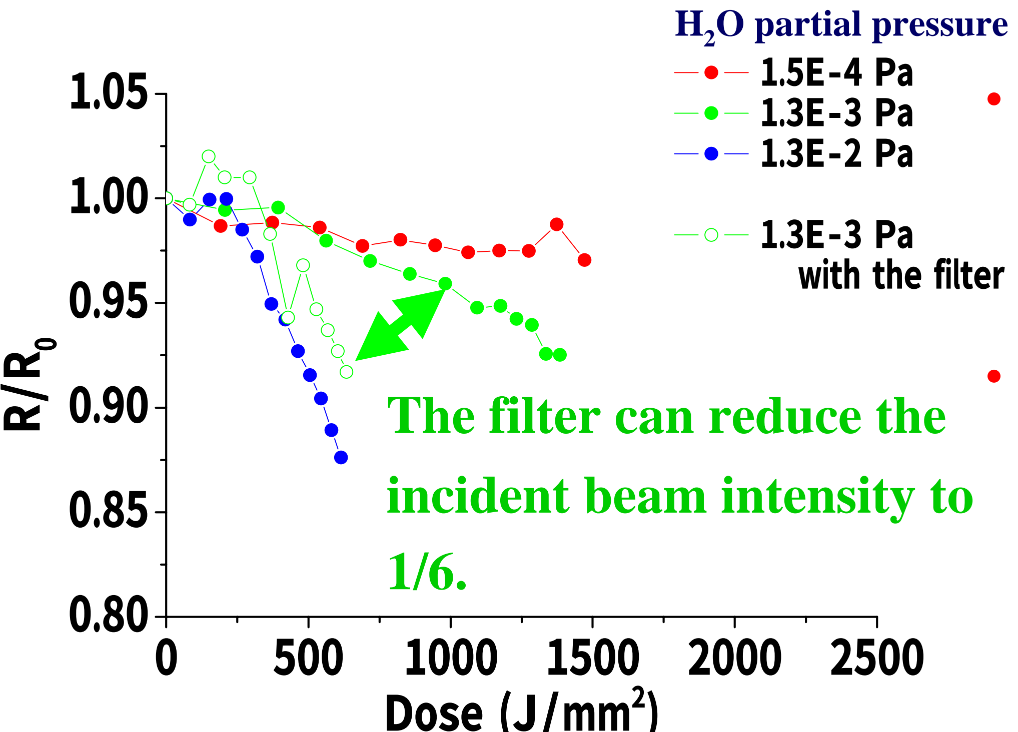
(mW/mm²)
554
443
332
222
111
0

200 mm
250 mm

Z / mm: -5.0, -5.5, -6.0, -6.5, -7.0
X / mm: -4.0, -3.5, -3.0, -2.5, -2.0

As 1000 times intense as the intensity of EUVL system

Reflectance drop (Si-capped sample)



- At the same intensity of beam flux, the rates of the reflectance drops were large at the higher water vapor pressures.
- At the same water vapor pressure, the rates of the reflectance drops became large at the weaker intensity of beam flux.

- The rate of reflectance drop was determined by both the water vapor pressure and the photon flux.
- At the highest intensity of photon flux, oxidation rate was controlled by the amount of water molecules.

Comparison between Ru- and Si-capped mirrors

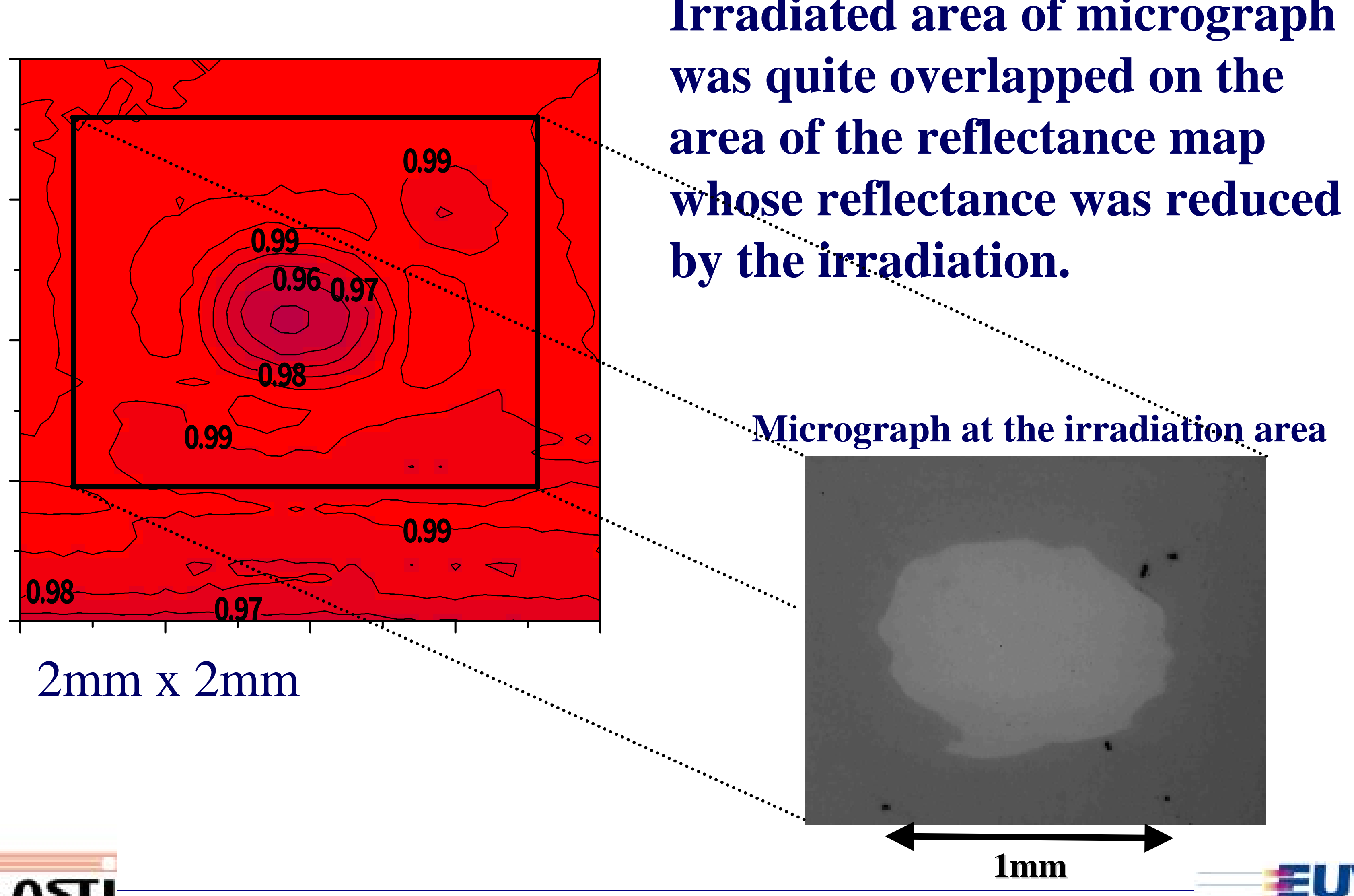
1.05
1
0.95
0.9
0.85
0.8
R/R0
0
500
1000
1500
2000
2500
Dose (J/mm2)

	Ru	Si
1.5E-4	●	■
1.3E-3	●	■
1.3E-2	●	■

Ru-capped sample kept higher reflectance in each pressure compared with Si-capped sample.

Reflectance map (Si-capped sample)

Irradiated area of micrograph was quite overlapped on the area of the reflectance map whose reflectance was reduced by the irradiation.



Results of XPS

- Oxidation was observed at the irradiation area.
- Carbon deposition was observed around the irradiation area.
- On the other hand, carbon was removed by the irradiation.

Irradiation area

Schematic view of the sample surface

3nm
C
Si
Mo
O
Atomic concentration (%)
0 5 10 15 20
Sputter time (min)

0.3nm 3nm
O
Mo
C
Si
Atomic concentration (%)
0 5 10 15 20 25
Sputter time (min)

See the poster CoP19 by Takase *et al.*, for more details

Comparison between photoemission and XPS measurements

(Carbon)

Photon energy: 295eV

On-line measurement of photoemission current around the irradiation area

Off-line measurement of XPS at the minimum reflectance on the sample surface

The photoemission current at the energy above carbon absorption edge was good agreement with the XPS signal intensity.

Conclusion

- **The EUV irradiation and reflectance measurement system using strong EUV source was developed at NewSUBARU. The system can perform *in-situ* reflectance measurements.**
- **Incident beam intensity was about 500 mW/mm^2 in the area of 200 x 250 μm^2.**
- **The rates of the reflectance drops scaled by the dose were large at the higher water vapor pressures within the same flux of incident beams and/or at the weaker flux of incident beam within the same water vapor pressures. It might be caused by the water vapor was not enough supplied.**
- **The Ru-capped sample was tolerant against oxidation as compared with the Si-capped sample.**

Conclusion (cont.)

- **Oxidation was progressed and carbon was removed at the irradiation area.**
- **Carbon deposition was progressed at the out of irradiation area.**

Acknowledgments

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