A New Contamination Evaluation System for EUVL Projection Mirrors in NewSUBARU

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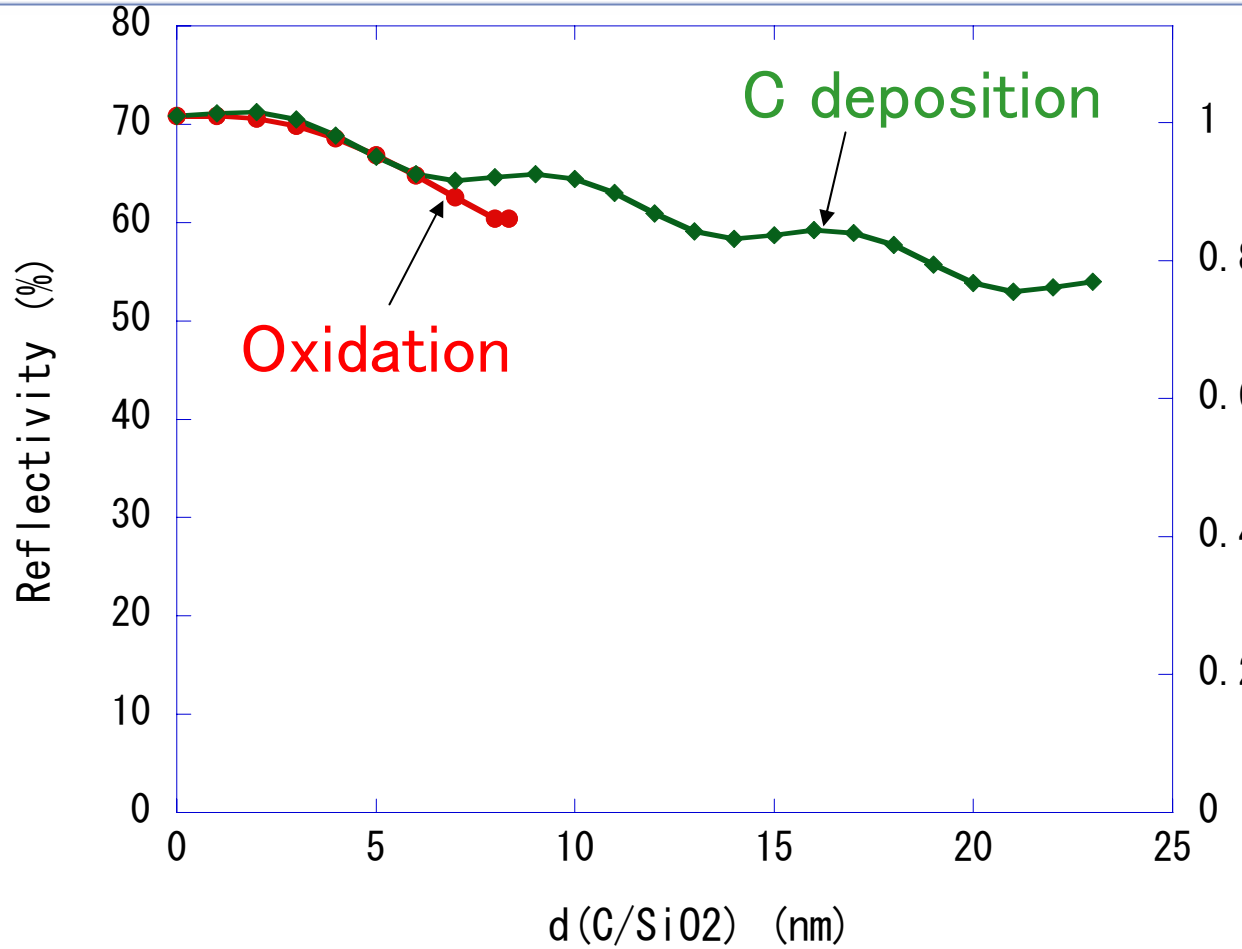
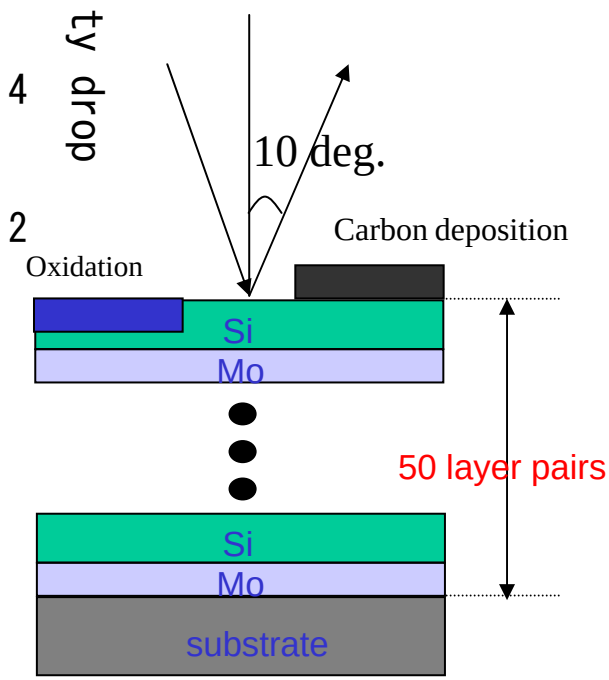
Background

- Contamination on the multilayer mirrors (MLMs) for EUVL optics is a significant problem in order to commercialize the EUV lithography.
- Last year, we reported the contamination evaluation system using high flux EUV radiation from the long undulator in NewSUBARU facility.
- As the system had a partly o-ring-sealed vacuum chamber and all of automatic stages inside the chamber, it was not suitable for precise control of vacuum atmosphere.

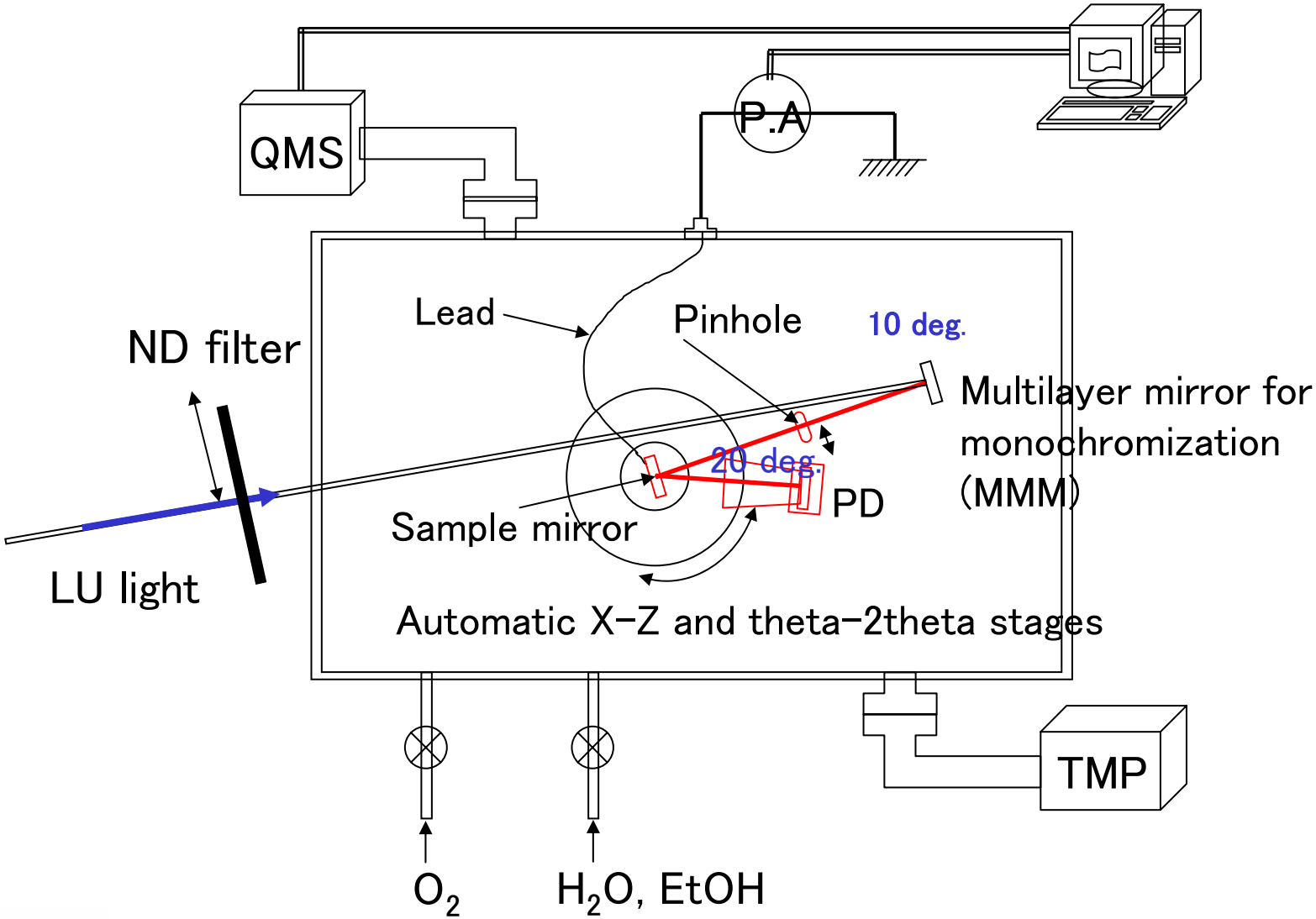
Calculated reflectance drop by carbon deposition or oxidation





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

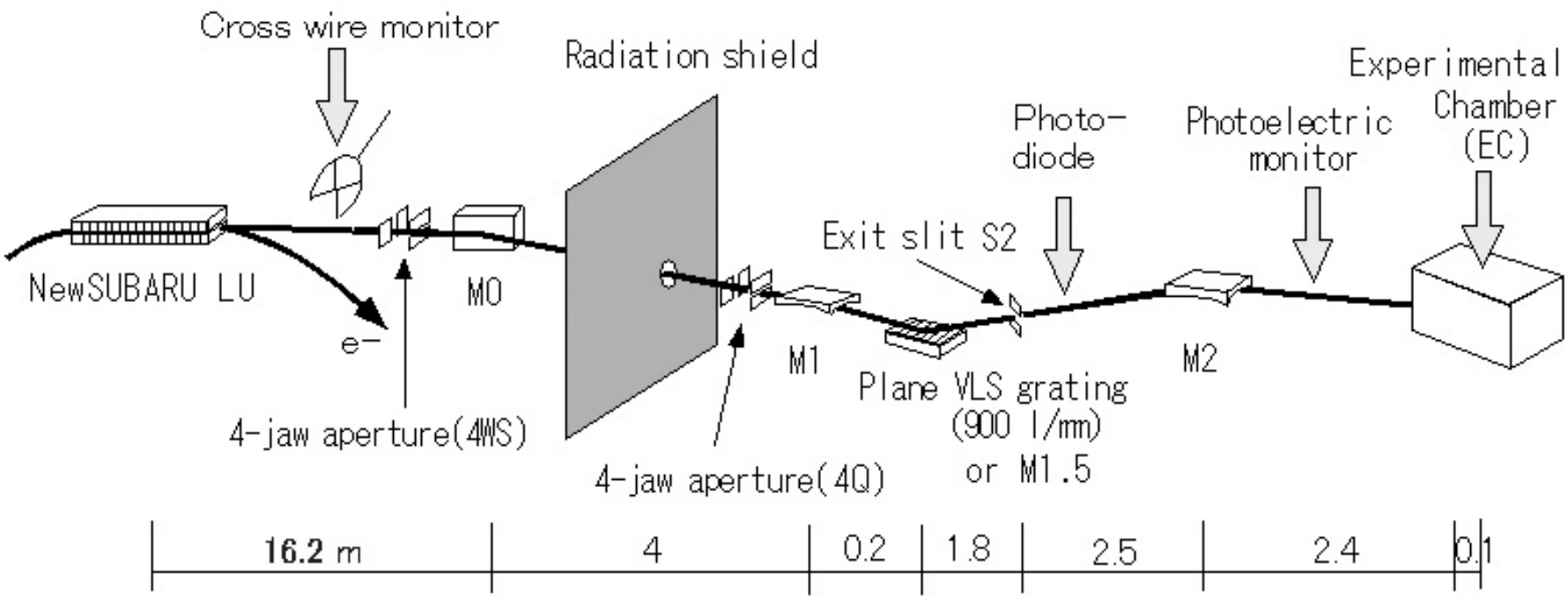
Previous Experimental System



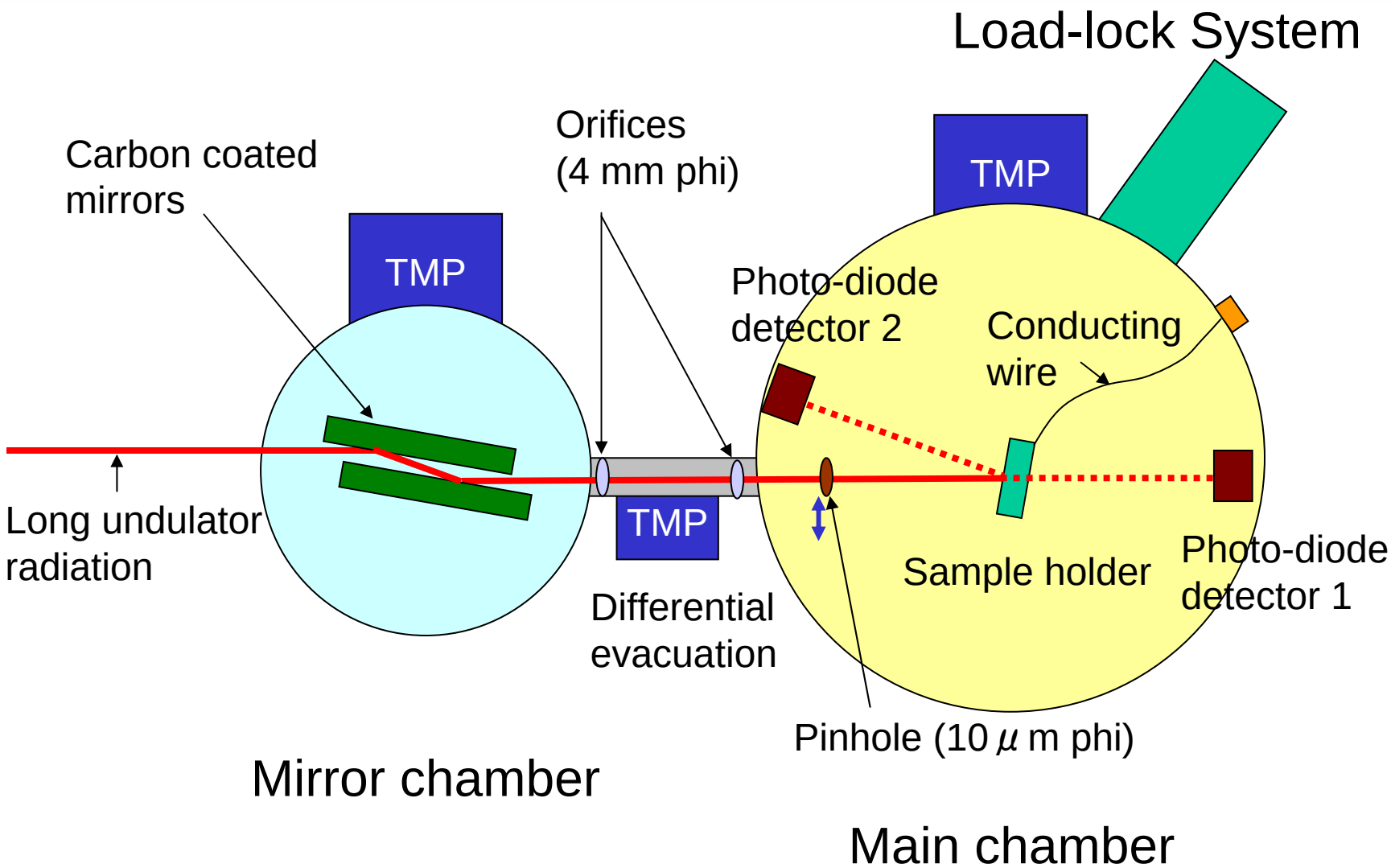
Purpose

- Developing a new contamination evaluation system, which had all metal-sealed vacuum chambers, to extend degrees of vacuum and to control the quantity of hydrocarbon component accurately.
- Carrying out the irradiation of Si-capped Mo/Si MLMs under the various water vapor pressure conditions as the first experiment.
- For *in-situ* observation of contamination, carrying out the NEXAFS spectroscopy at the irradiation area and comparing with off-line surface analysis.

Long Undulator Beam Line at NewSUBARU

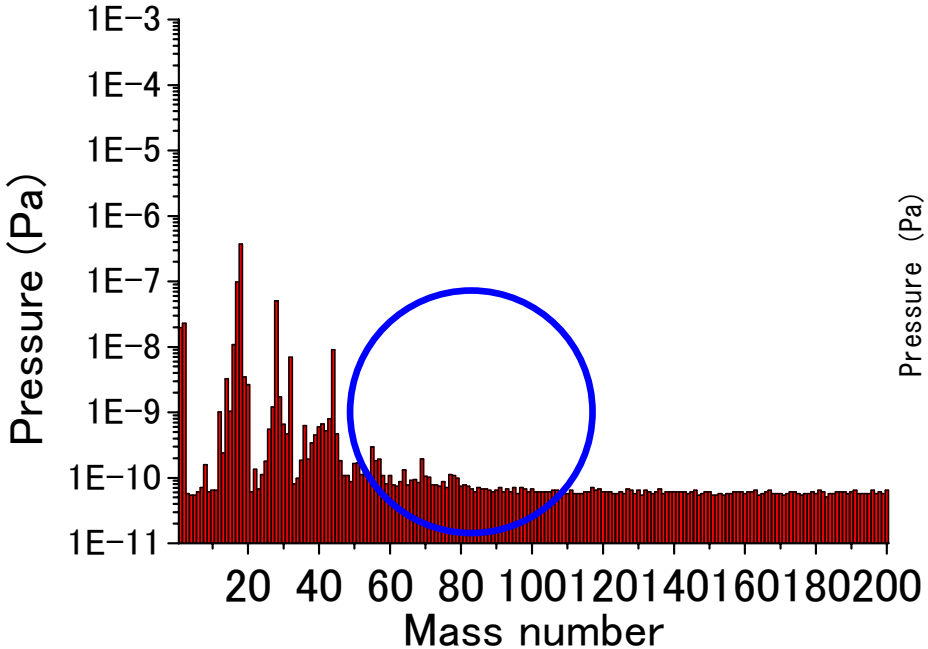


New Contamination Evaluation System

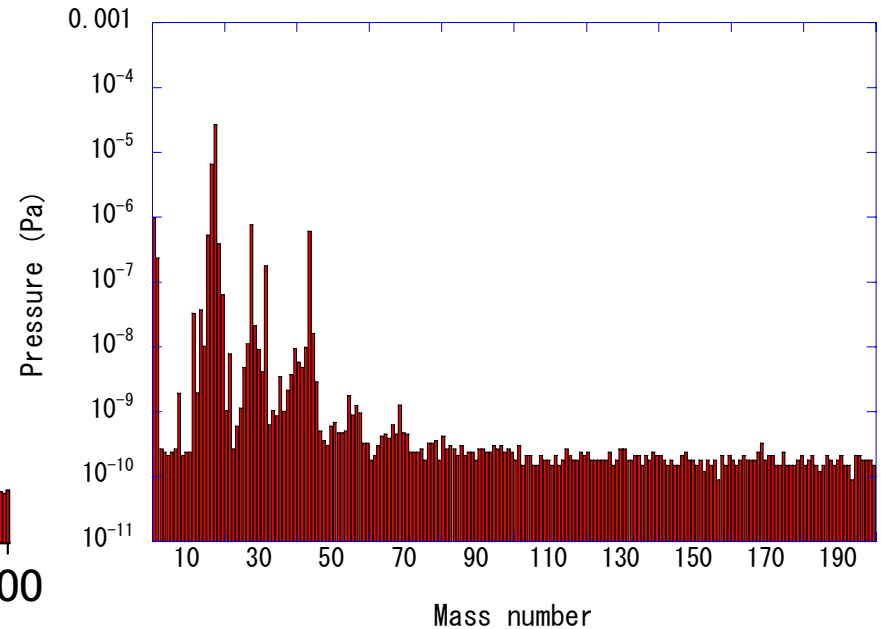


QMS analysis

New chamber
(3.7E−7 Pa)

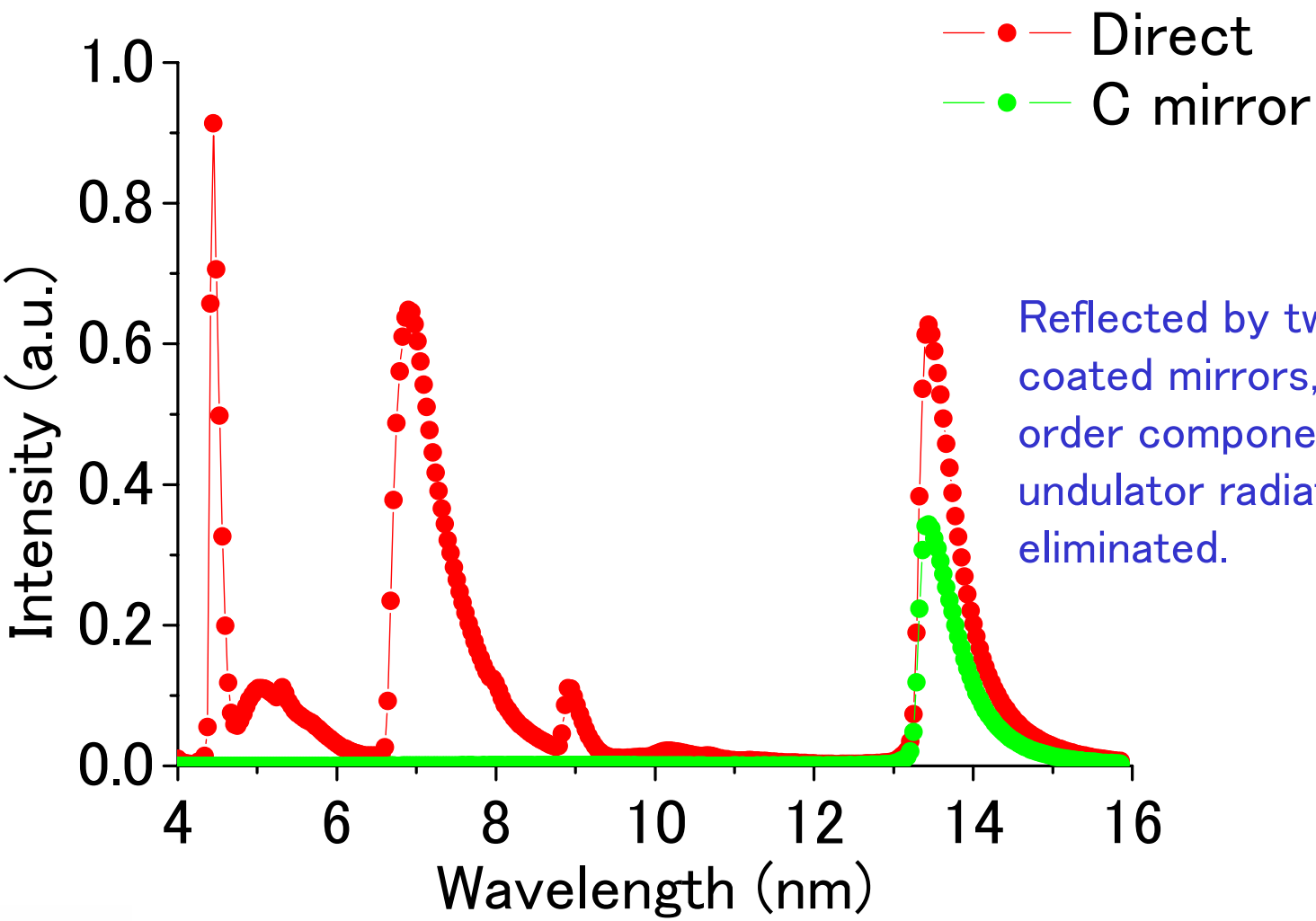


Previous chamber
(4.5E−5 Pa)



Amount of hydrocarbon was decreased in the new chamber.

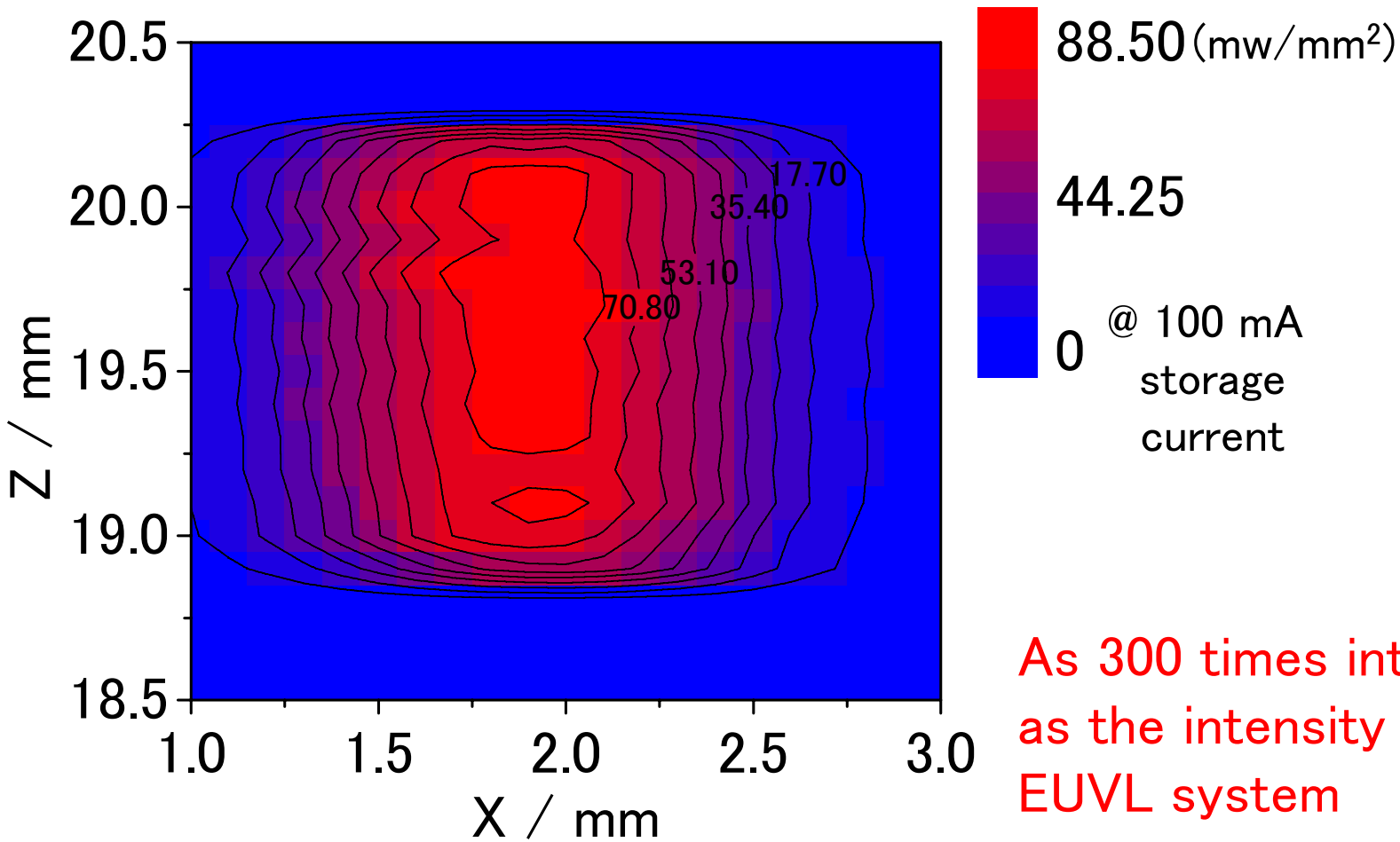
Spectra of Irradiation Beam



Reflected by two carbon coated mirrors, the higher order components of undulator radiation were eliminated.

Profile of Irradiation Beam

~200 mW/mm^2 +/- 10%, @ 0.24 (w) x 0.32 (H) mm^2 area



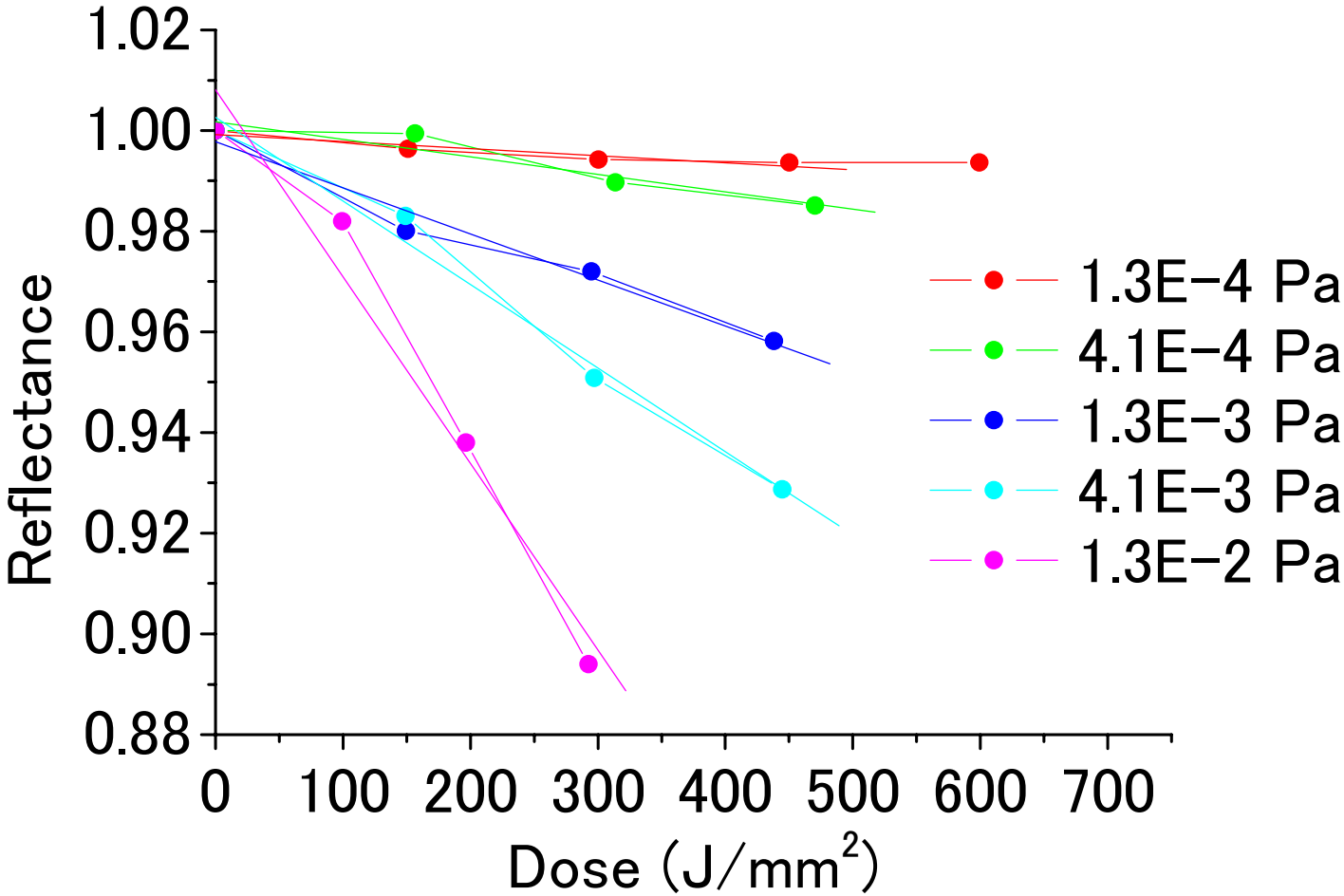
As 300 times intense as the intensity of EUVL system

Comparison of Former and Present System

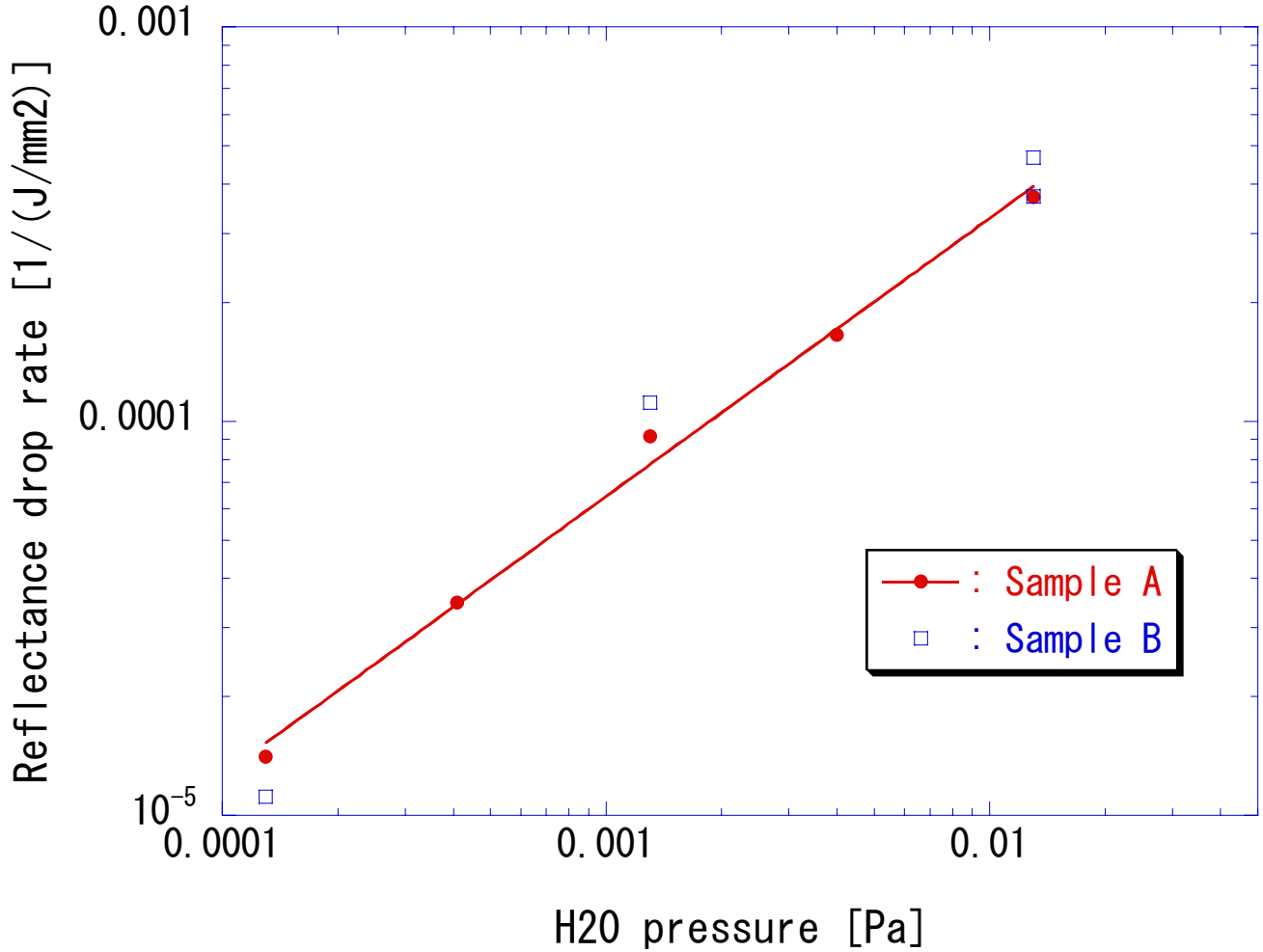
System	previous	present
Ultimate pressure	5 E-5 (Pa)	3 E-7 (Pa)
Automatic stages	Inside the chamber	Driven from outside of the chamber
Flux density	500 (mW/mm^2)	200 (mW/mm^2)
Beam size	0.38(w) x 0.2 (mm^2)	0.24(w) x 0.32 (mm^2)

Reflectivity Drop of Si-capped Mirrors by Irradiation

Flux density : 100 – 200 (mW/mm^2)

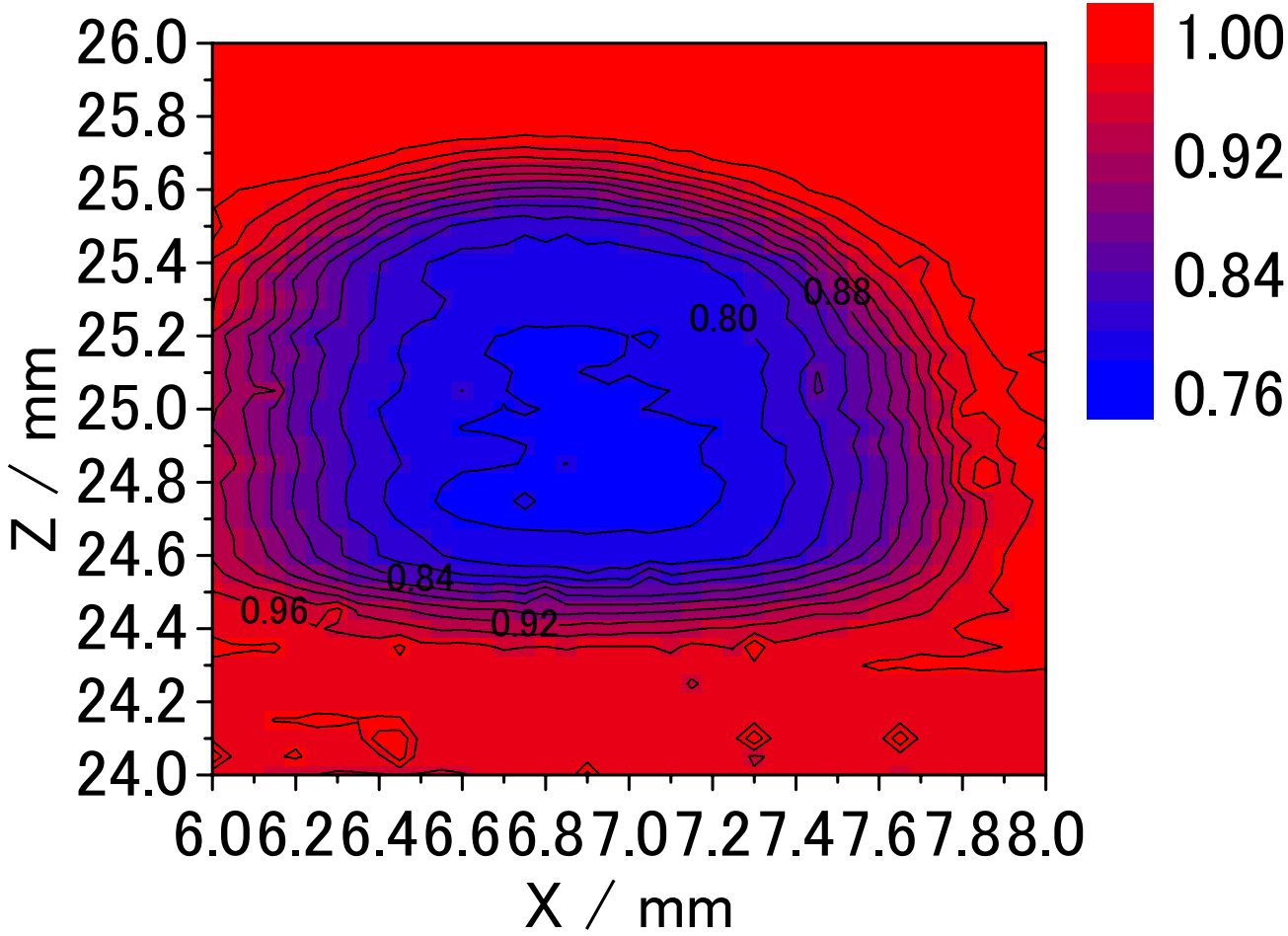


Reflectance drop rate (Si-capped samples)



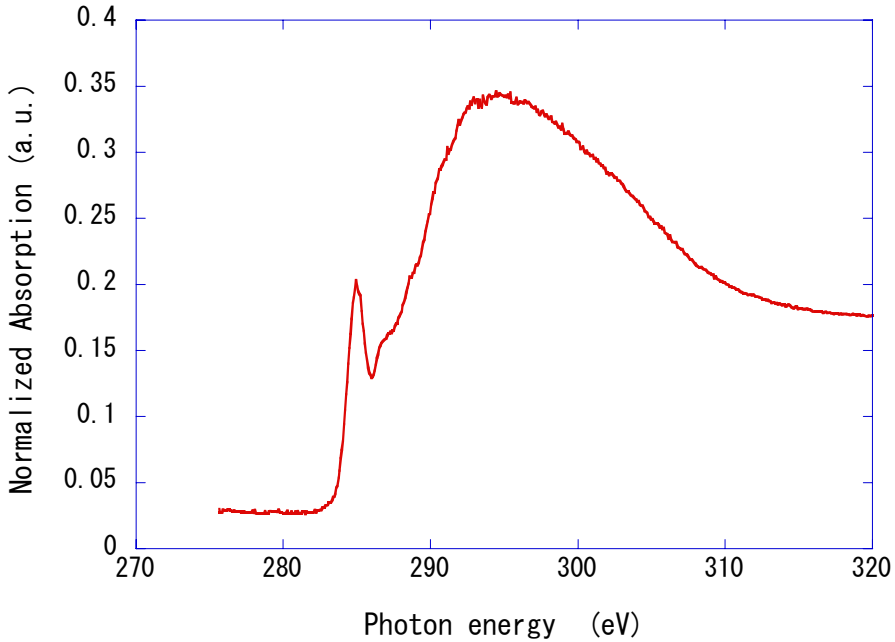
- Sample A and Sample B were prepared by different deposition systems.

Reflectance map of irradiated area (Si-cap MLM)

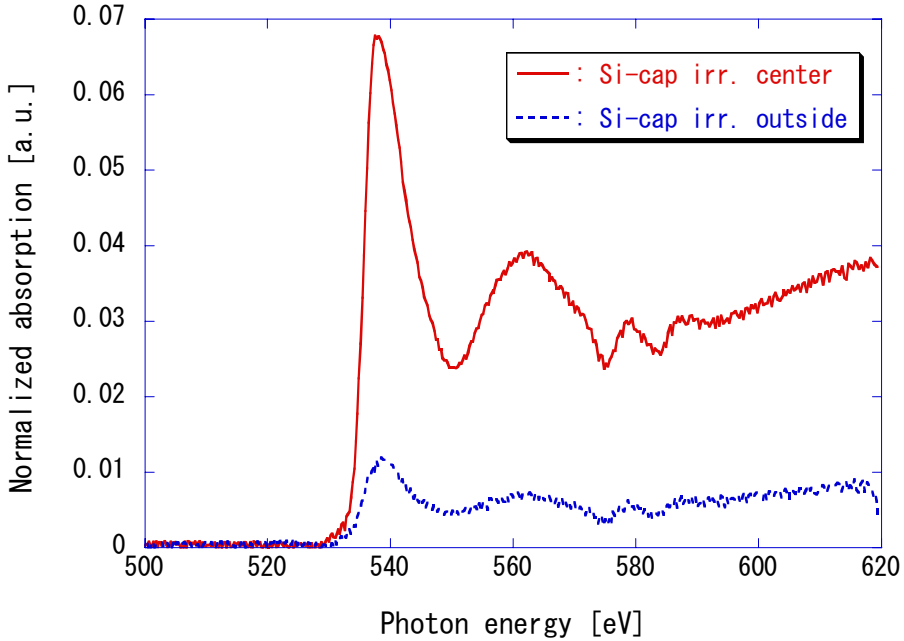


NEXAFS Spectra of C and O K-edge

- Using the beam line monochromator, pinhole and conducting lead, NEXAFS spectra and intensity map of C and O K-absorption edge was obtained in the irradiation area.



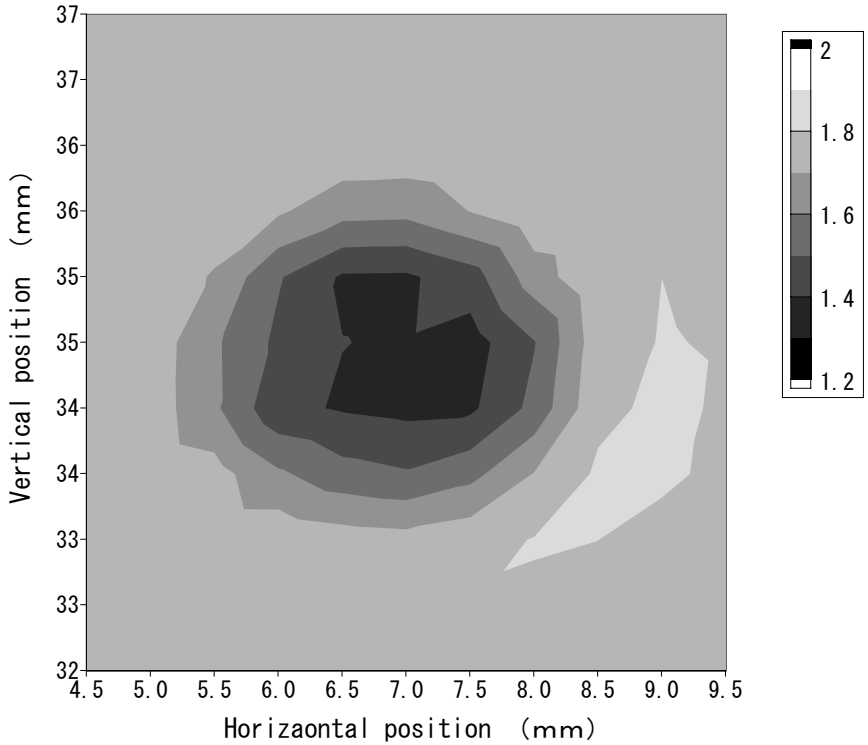
C K-edge absorption



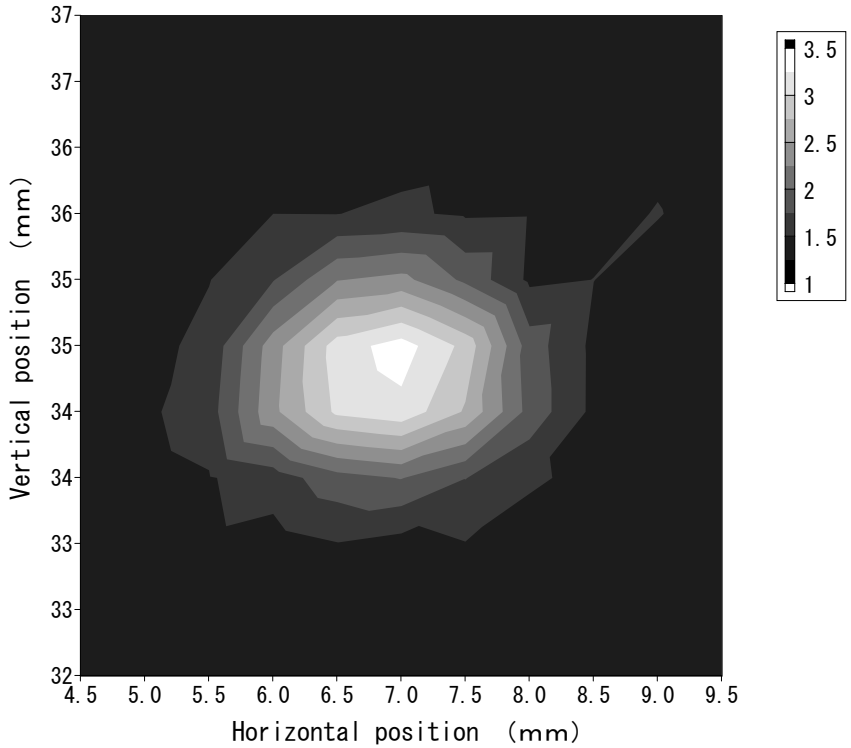
O K-edge absorption

Carbon and Oxygen Intensity Map of Irradiated Area

Carbon {I(292 eV)/I(282eV)}



Oxygen {I(539 eV)/I(506eV)}



- Oxidation was increased at the irradiation center.
- Carbon was decreased at the center and slightly increased around the irradiation area.

Results of off-line XPS analysis

P_{H2O}	Position	C (atom %)	$SiO_X/(SiO_X+Si)$
4.1 E-4 (Pa)	irradiation center	8.7	78.6
	reference (outside)	19.4	52.4
1.3 E-3 (Pa)	irradiation center	4.9	88.7
	reference (outside)	17.1	53.4
1.3 E-2 (Pa)	irradiation center	4.7	96.9
	reference (outside)	13.9	48.4

NEXAFS map is qualitatively consistent with the results of off-line XPS.

Conclusion

- A new EUV irradiation and reflectance measurement system using strong EUV source was developed at NewSUBARU. The system had all metal-sealed chambers and outside stage drivers, which was suitable to extend degrees of vacuum and to control the quantity of hydrocarbon component.
- The rates of reflectance drops of Si-capped MLMs were related to the logarithm of water vapor pressures.
- In-situ NEXAFS spectra and the element map of irradiated area was successfully obtained with beamline monochromator and sample current method. The element map was qualitatively consistent with the results of off-line XPS analysis.

Acknowledgments

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