In situ XANES Analysis for EUVL Projection Optics Contamination

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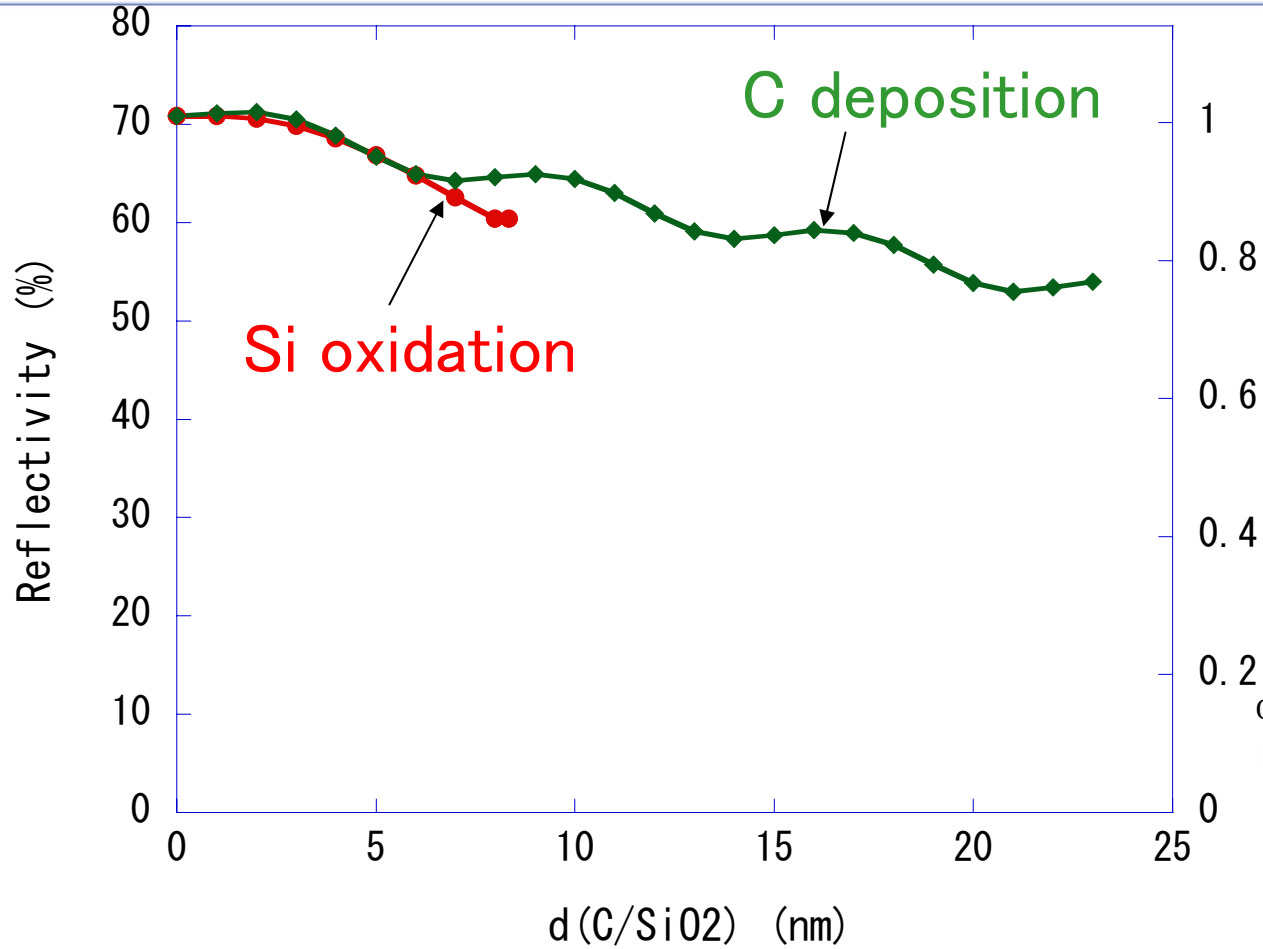
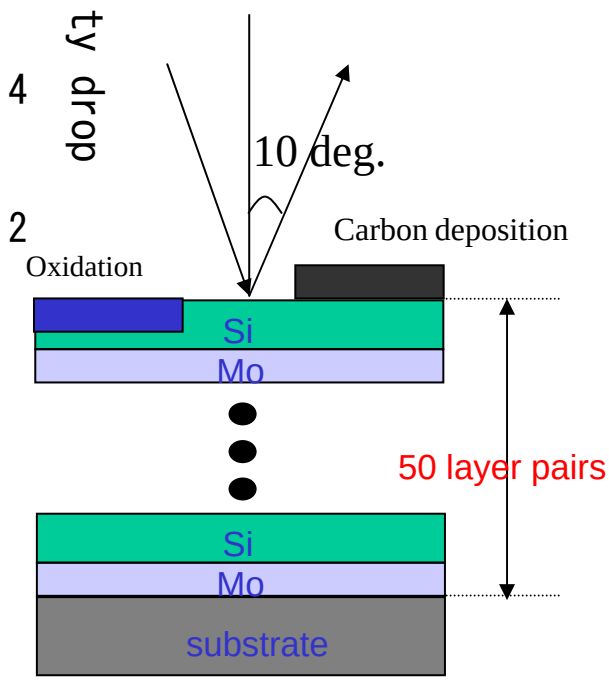
Background

- **Contamination on the multilayer mirrors (MLMs) for EUVL optics is a significant problem in order to commercialize the EUV lithography.**
- **To investigate optics contamination, surface analysis is an important technique in addition to high flux EUV irradiation source and precise reflectometry.**
- **In particular, *in situ* observation technique provides very important information for understanding contamination phenomena.**

Calculated reflectance drop by carbon deposition or Si oxidation



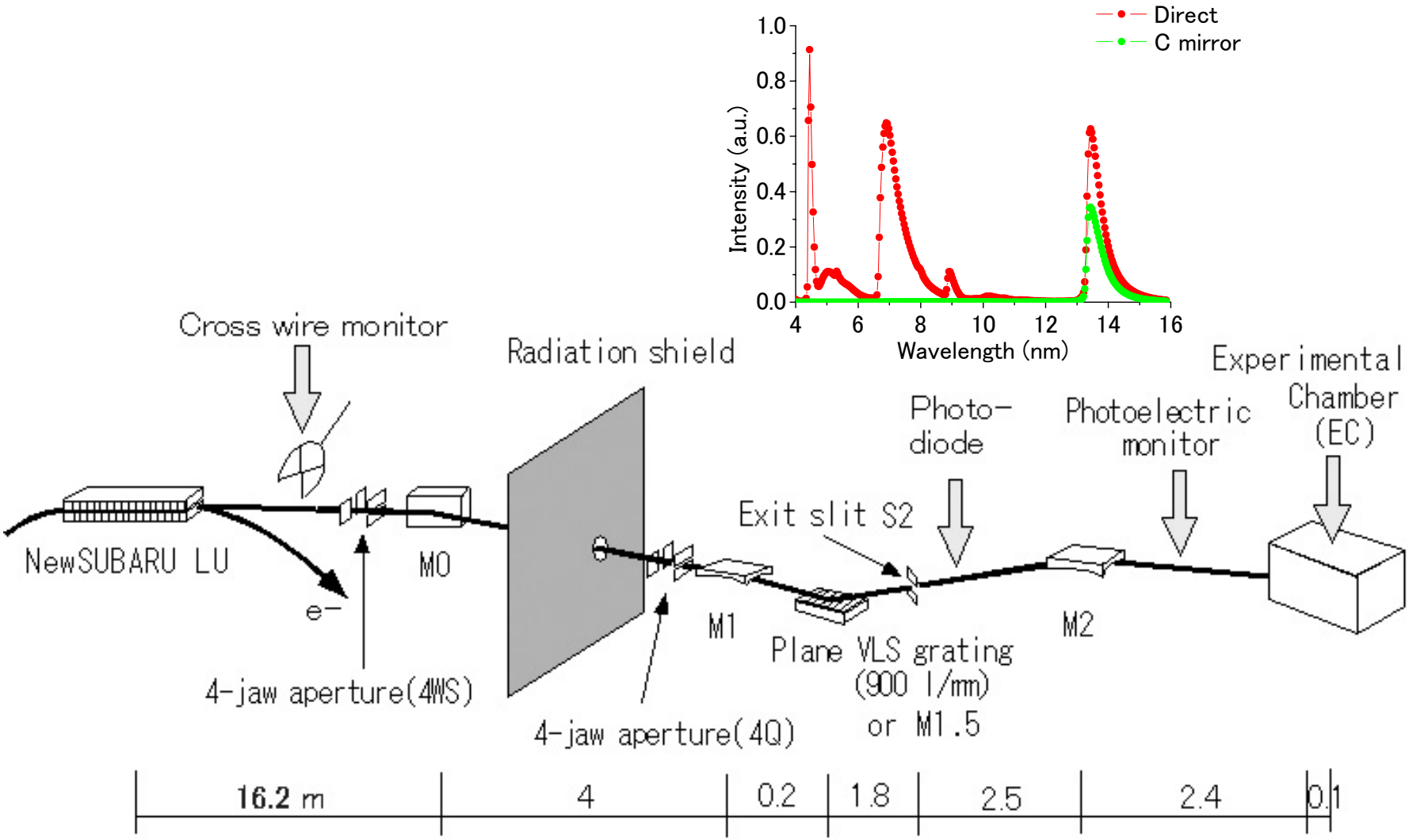


Even though the thickness of contamination is a few nm, the reflectance is reduced in a few percents .

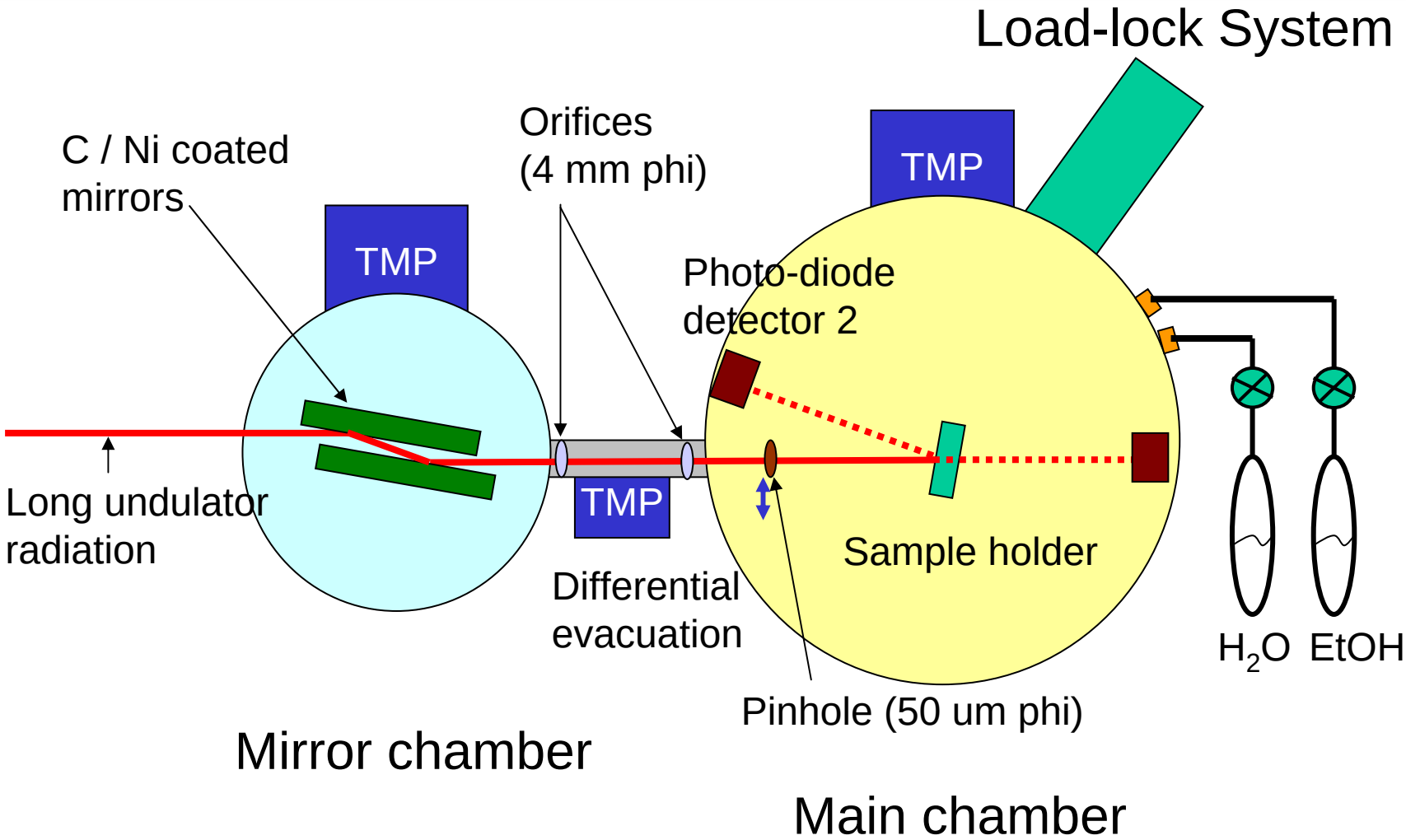
Outline of this work

- **An *in situ* X-ray absorption near edge structure (XANES) spectrometry technique was developed in the contamination evaluation system at the NewSUBARU SR facility.**
- **Surface state analysis and elemental concentration mapping were carried out by XANES technique for the EUV irradiated Si- and Ru-capped Mo/Si MLMs.**
- **The results of *in situ* observation of the sample, the contamination of which was controlled by ethanol introduction, were qualitatively agree with that of off-line XPS analysis.**

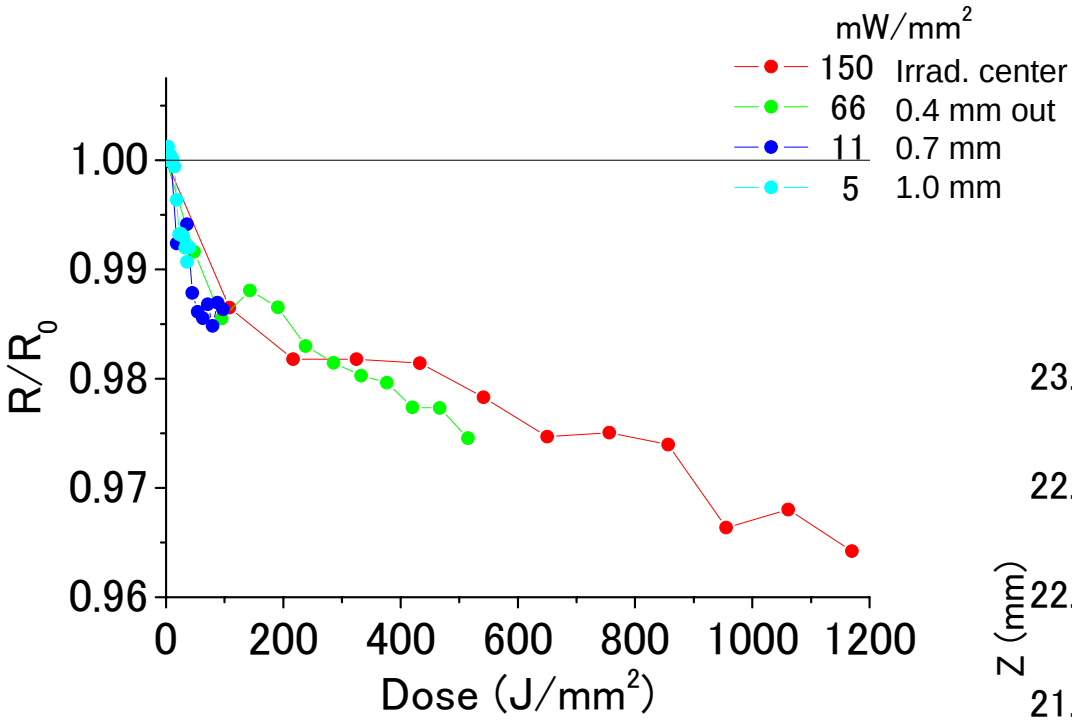
Long Undulator Beam Line at NewSUBARU



Contamination Evaluation System

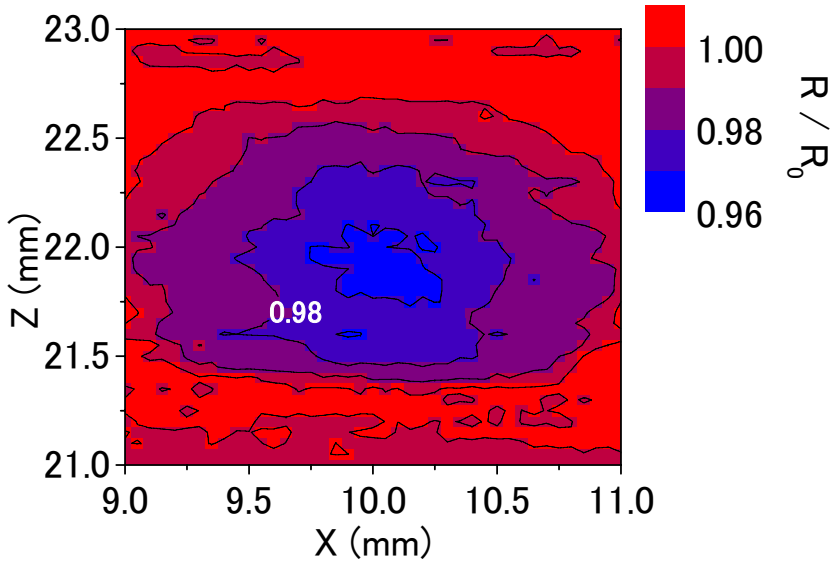


Reflectivity change and map of MLM by EUV irradiation



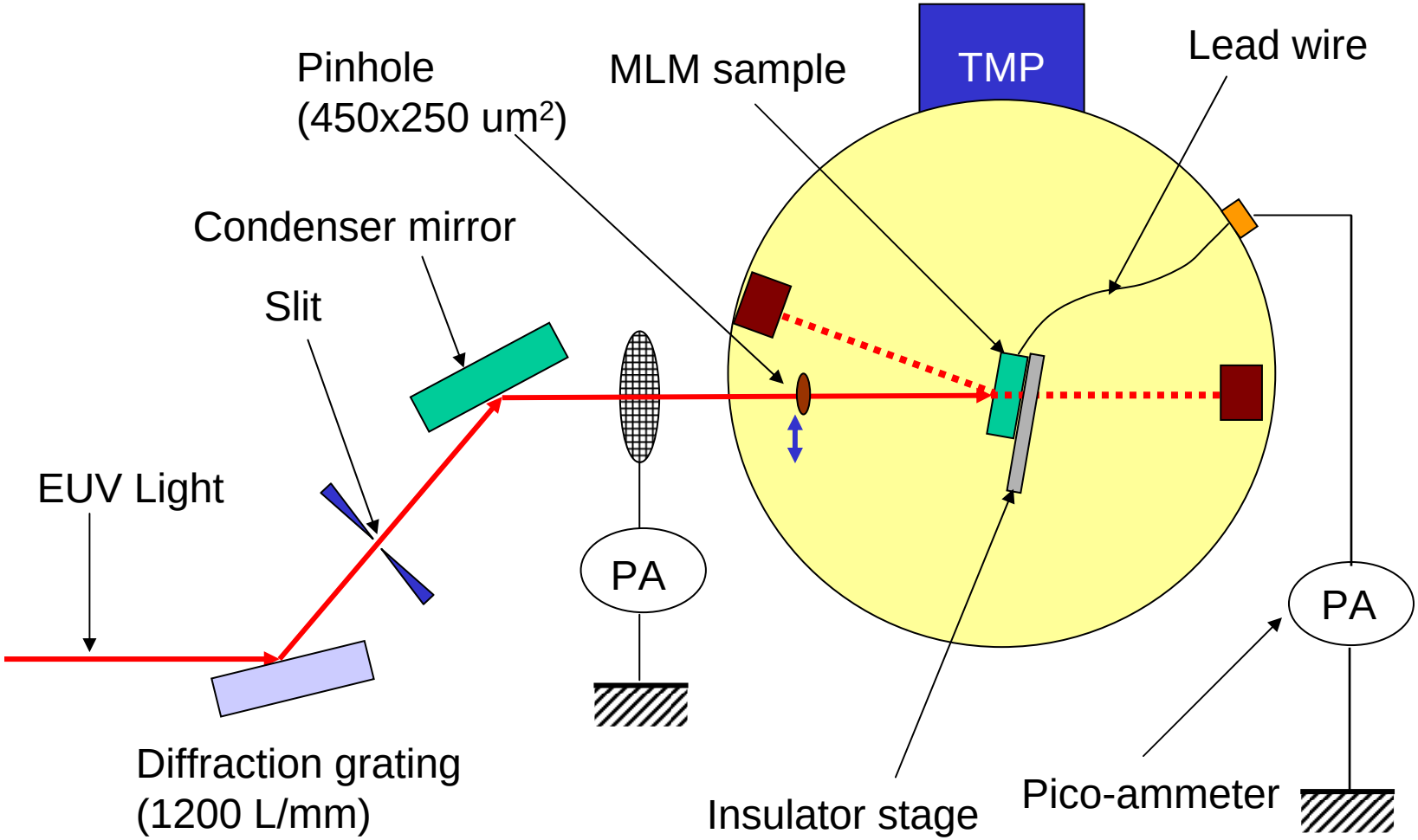
Dose dependence of reflectivity of Ru-capped Mo/Si MLM.

Using a 50 um phi pinhole, local reflectivity of the sample was measured.



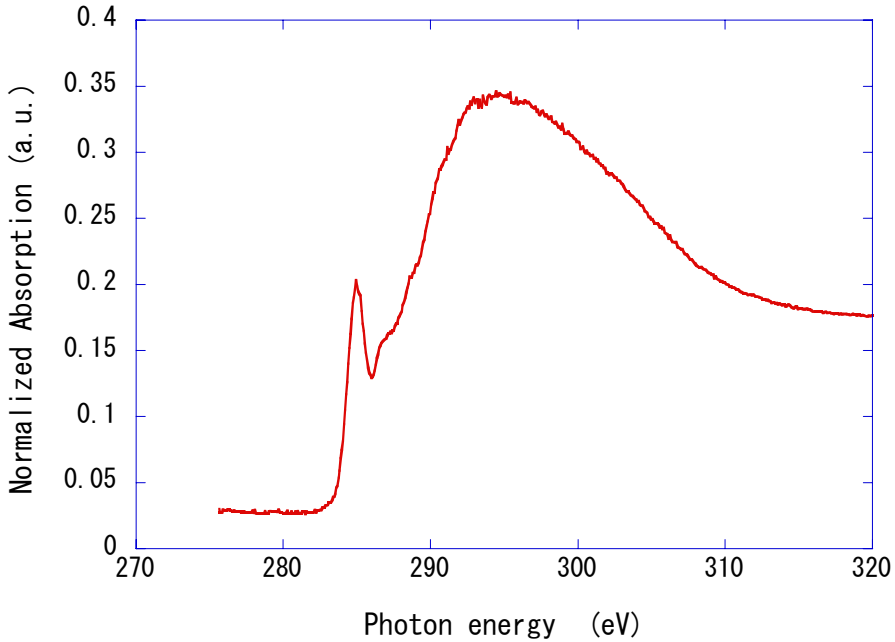
Reflectivity distribution map

In situ XANES measurement system

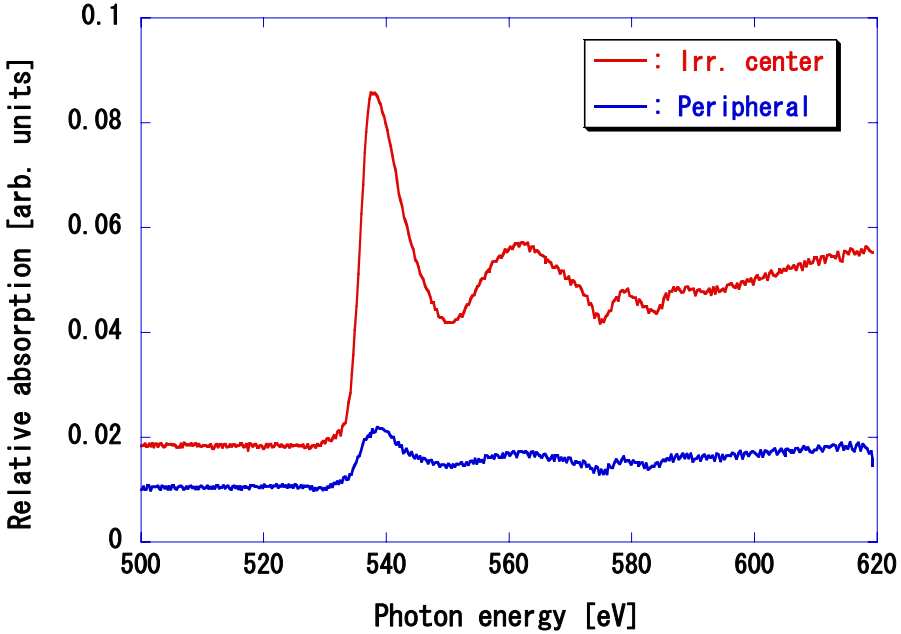


XANES Spectra of C- and O-K edges

- XANES spectra of C- and O-K absorption edges of heavily EUV irradiated Mo/Si MLM samples were obtained from the surface of the irradiated area.

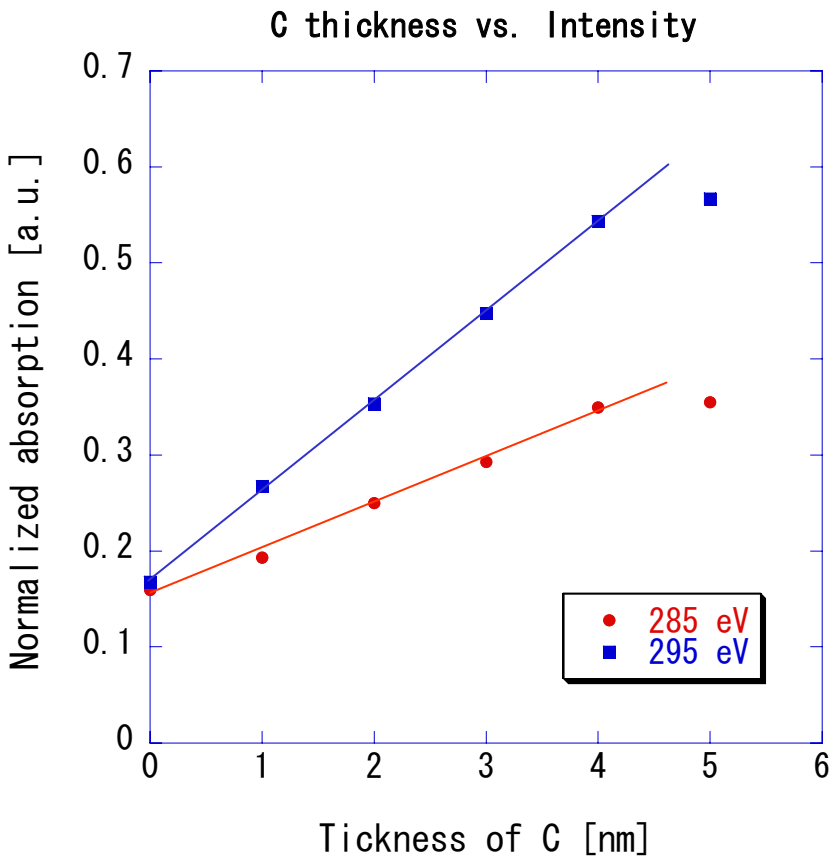


C-K absorption edge

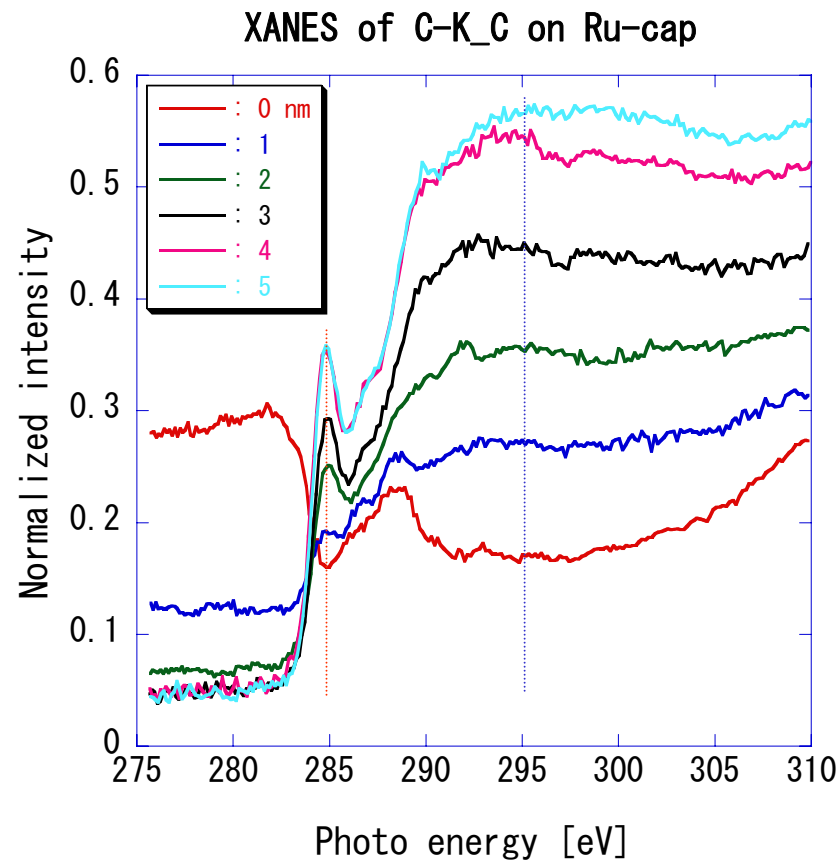


O-K absorption edge

Working curves of C-K absorption intensity vs. C film thickness



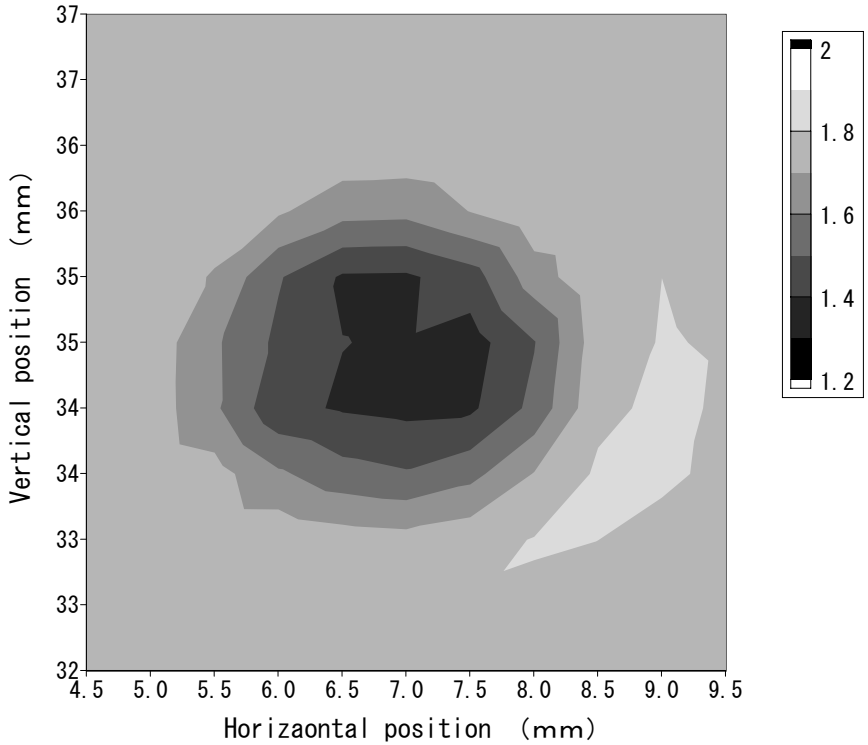
Working curves



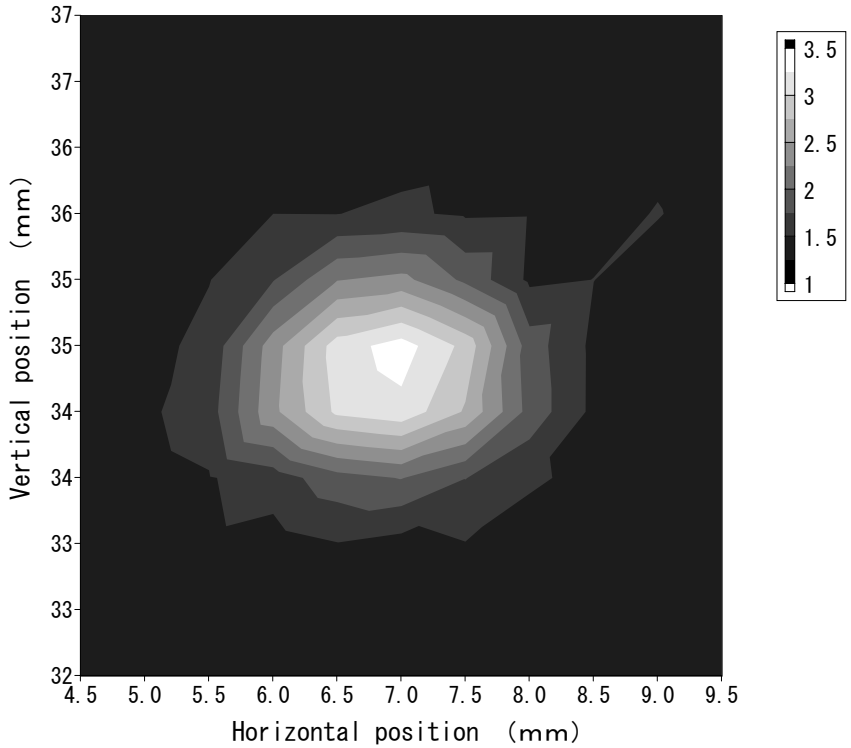
C-K XANES spectra of standard C thin films deposited on the Ru-capped Mo/Si MLMs

Carbon and Oxygen concentration map for Si-capped MLMs

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

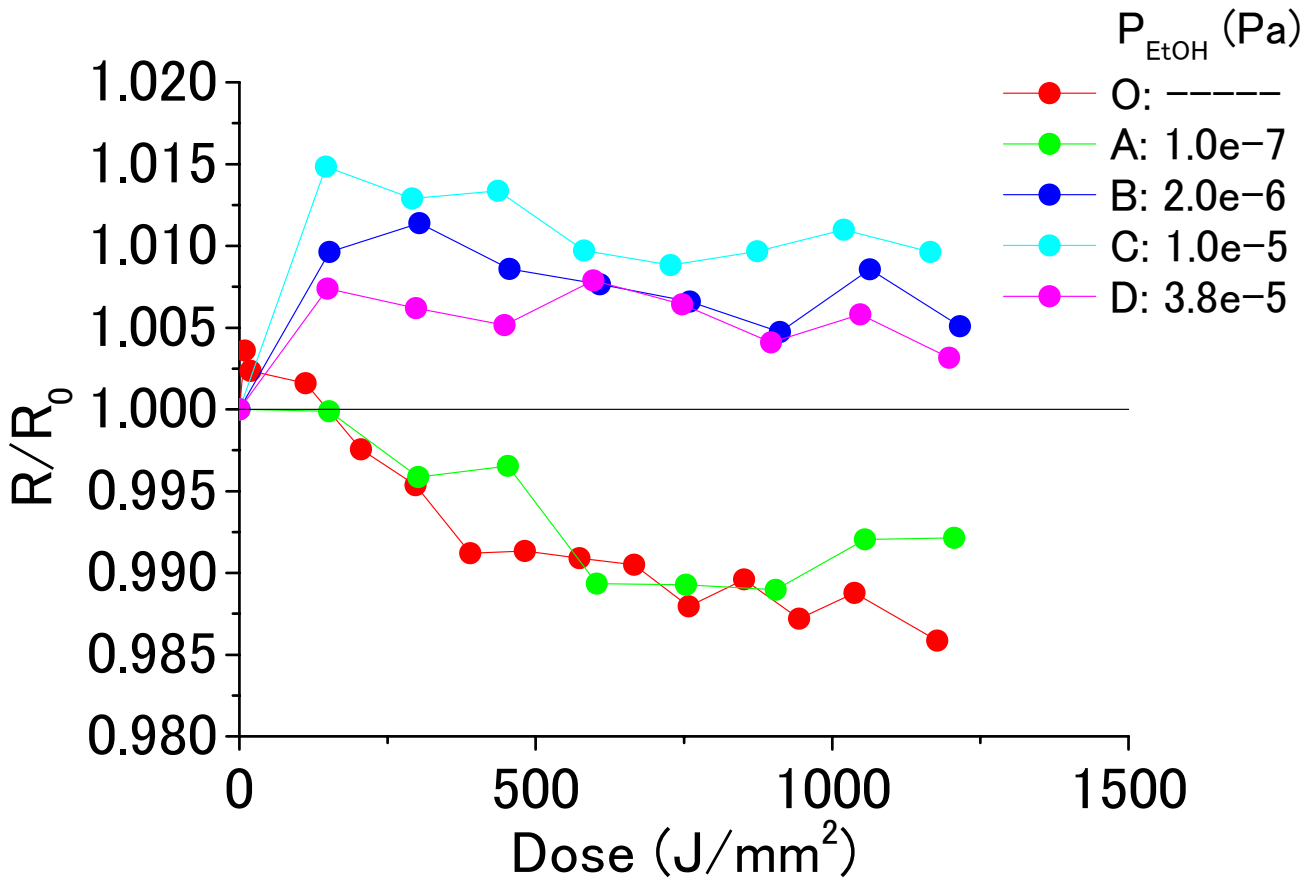


Oxygen {I(539 eV)/I(506eV)}



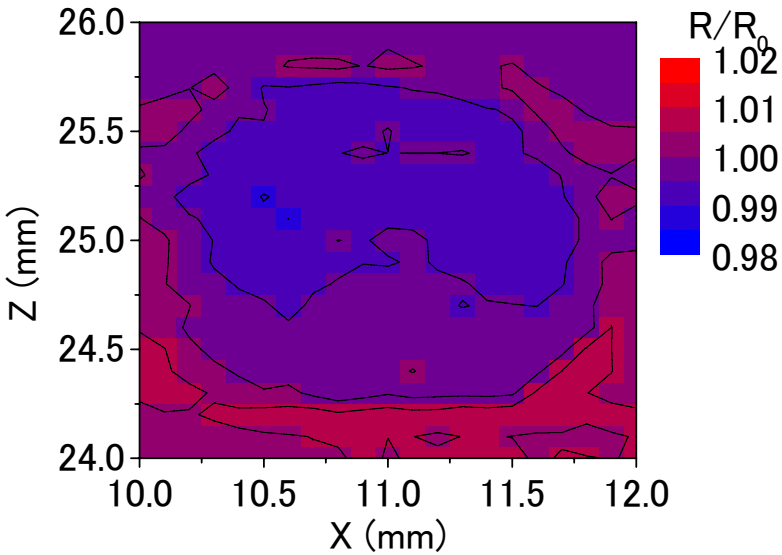
- Oxygen was increased at the irradiation center.
- Carbon was decreased at the center and slightly increased around the irradiated area.

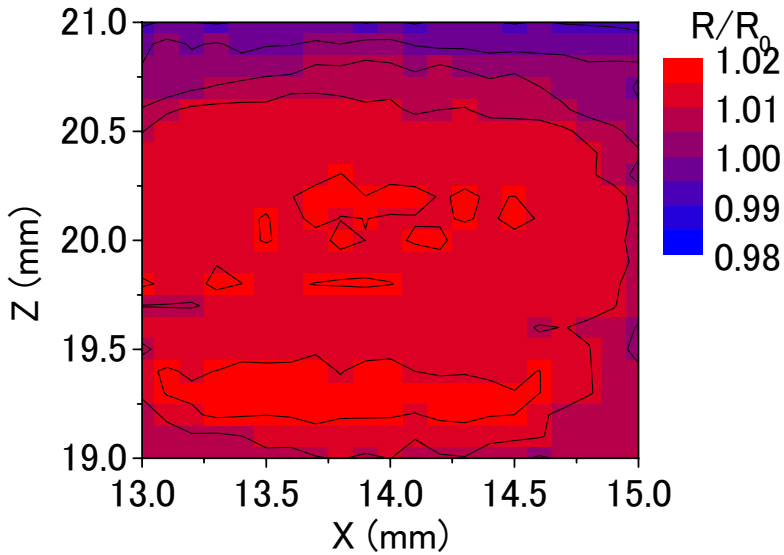
Contamination control by Ethanol introduction



Flux density: 150-170 mW/mm^2, Dose: 1200J/mm^2

Reflectivity map after irradiation





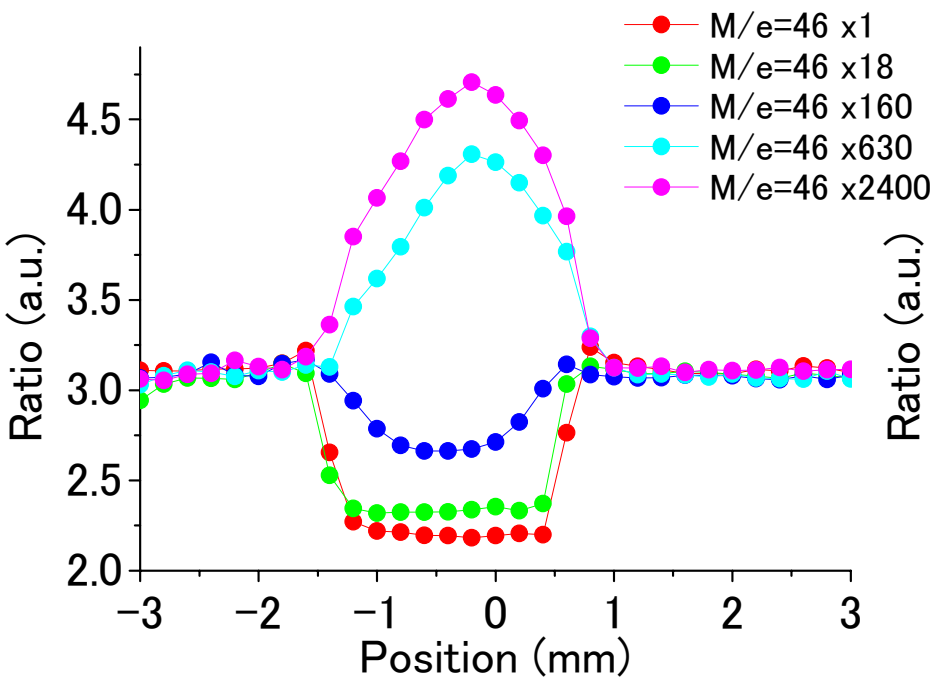
Condition O: H_2O only

Condition B:
H_2O + EtOH 2.0e-6 Pa

Reflectivity drop was inhibited over the whole irradiated area by EtOH introduction .

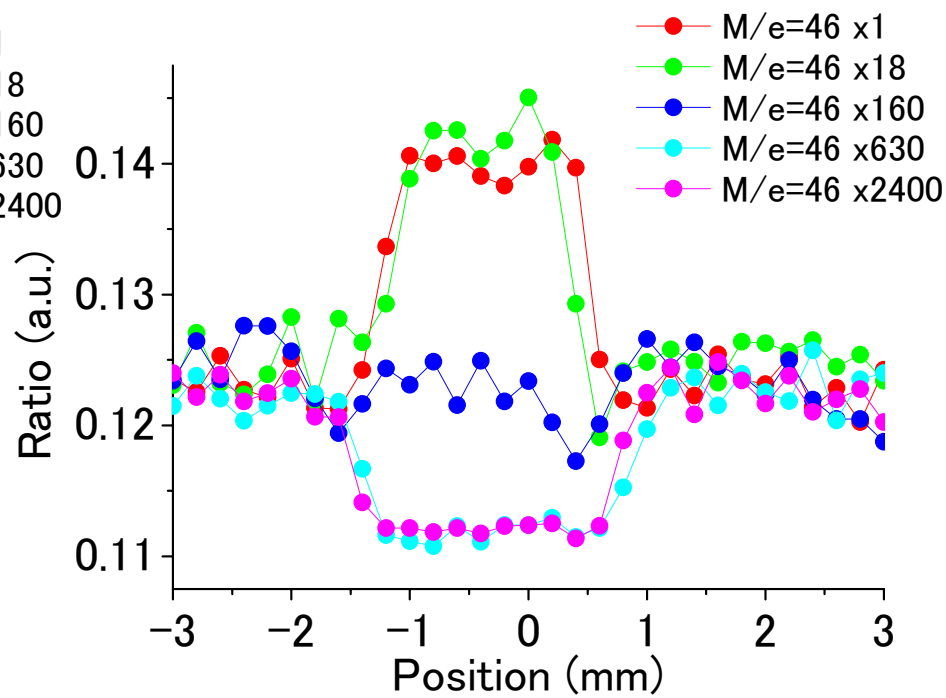
EtOH amount dependence of element concentration

I(293 eV)／I(279 eV)



Carbon concentration map at the irradiated area of MLM sample in EtOH introduced atmosphere.

I(541 eV)／I(517 eV)



Oxygen concentration map at the irradiated area of MLM sample in EtOH introduced atmospere.

Results of off-line XPS analysis

EtOH	O (%)	C (%)	Mo (%)	Si (%)	Ru(3d)
X 2400	27.7	41.6	0.5	8.2	18.5
X 630	28.2	42.1	0.5	10.6	18.6
X 160	36.9	24.2	0.6	13.1	25.1
X 18	42.8	24.4	0.6	11.0	21.3
X 1	42.2	19.7	0.7	12.5	24.9
Ref.	35.3	35.3	0.5	9.9	19.1

EtOH	SiOx/(SiOx+Si)	RuOx/(RuOx+Si)
X 2400	60.5 (%)	25.9 (%)
X 630	62.9	25.6
X 160	65.2	33.1
X 18	64.2	60.6
X 1	64.2	52.2
Ref.	61.6	42.8

: increase

: decrease

Concentration maps obtained by in-situ XANES are qualitatively consistent with the results of off-line XPS.

Conclusion

- A contamination evaluation system was developed at the NewSUBARU SR facility. The system has an *in situ* XANES measurement equipment for surface analysis.
- XANES spectra of C-K and O-K edges were successfully obtained for the samples of Si- and Ru-capped MLMs.
- The elemental concentration map of Ru-capped sample, the contamination of which was controlled by ethanol introduction, was qualitatively agree with the off-line XPS analysis.
- The *in situ* XANES analysis is a simple and useful technique to understand the optics contamination phenomena.

Acknowledgments

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