
Analysis of EUVL optics contamination using *in situ* XANES technique

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Colleague

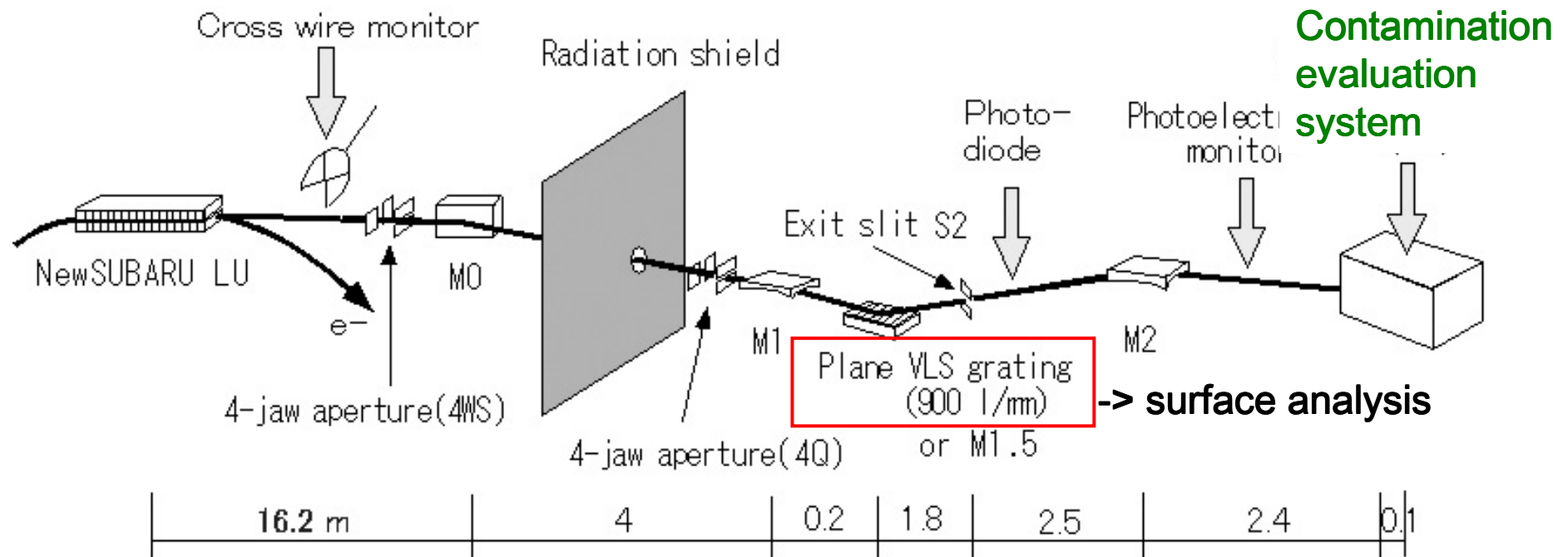
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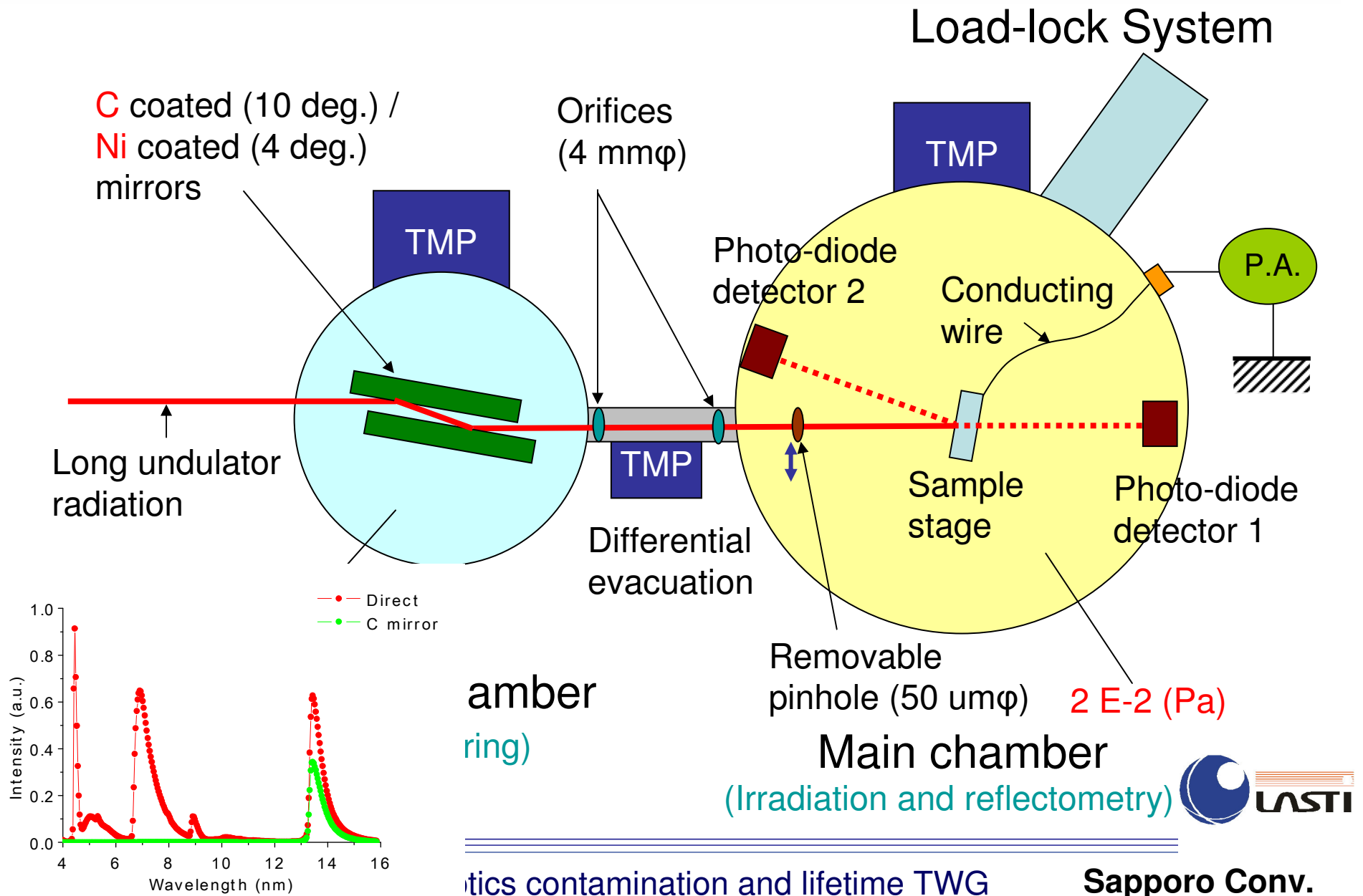


Long Undulator Beam Line at NewSUBARU

- Our contamination evaluation system was installed at BL9.
- High flux density EUV irradiation ($\sim 200 \text{ mW/mm}^2$) can be carried out with the use of undulator radiation.

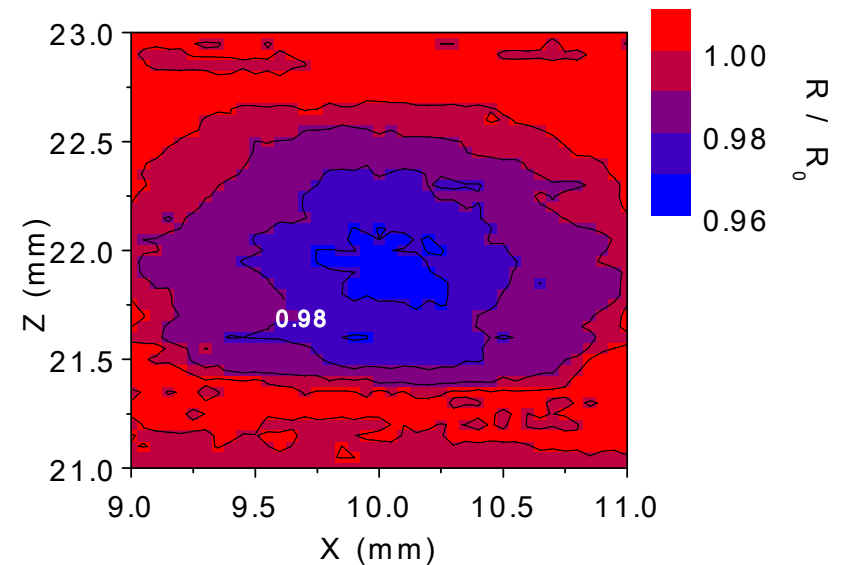
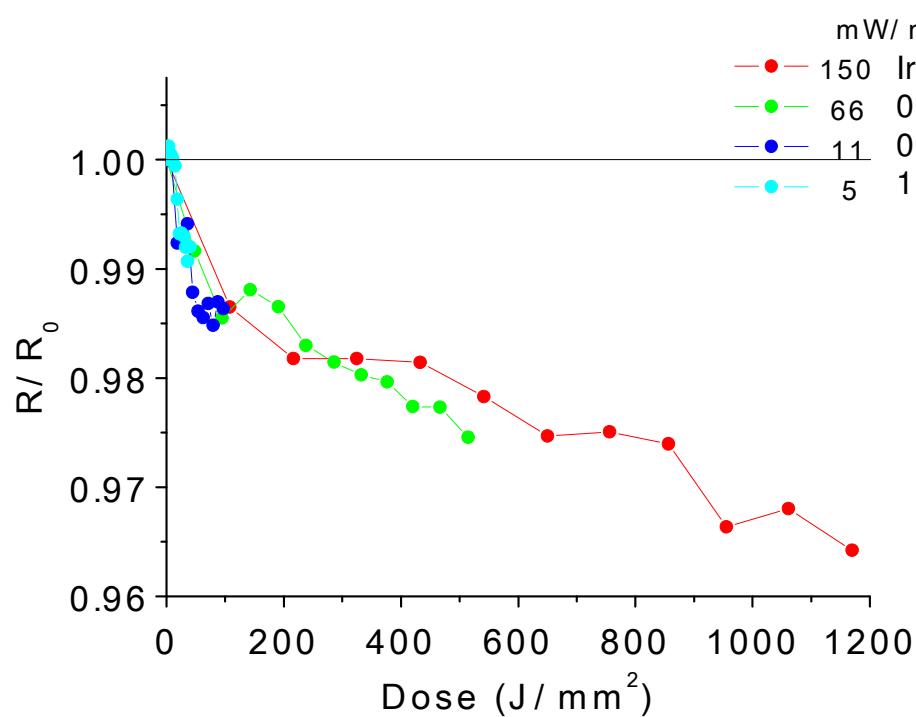


Contamination Evaluation System in NS



Reflectivity change and map of EUV irradiated area

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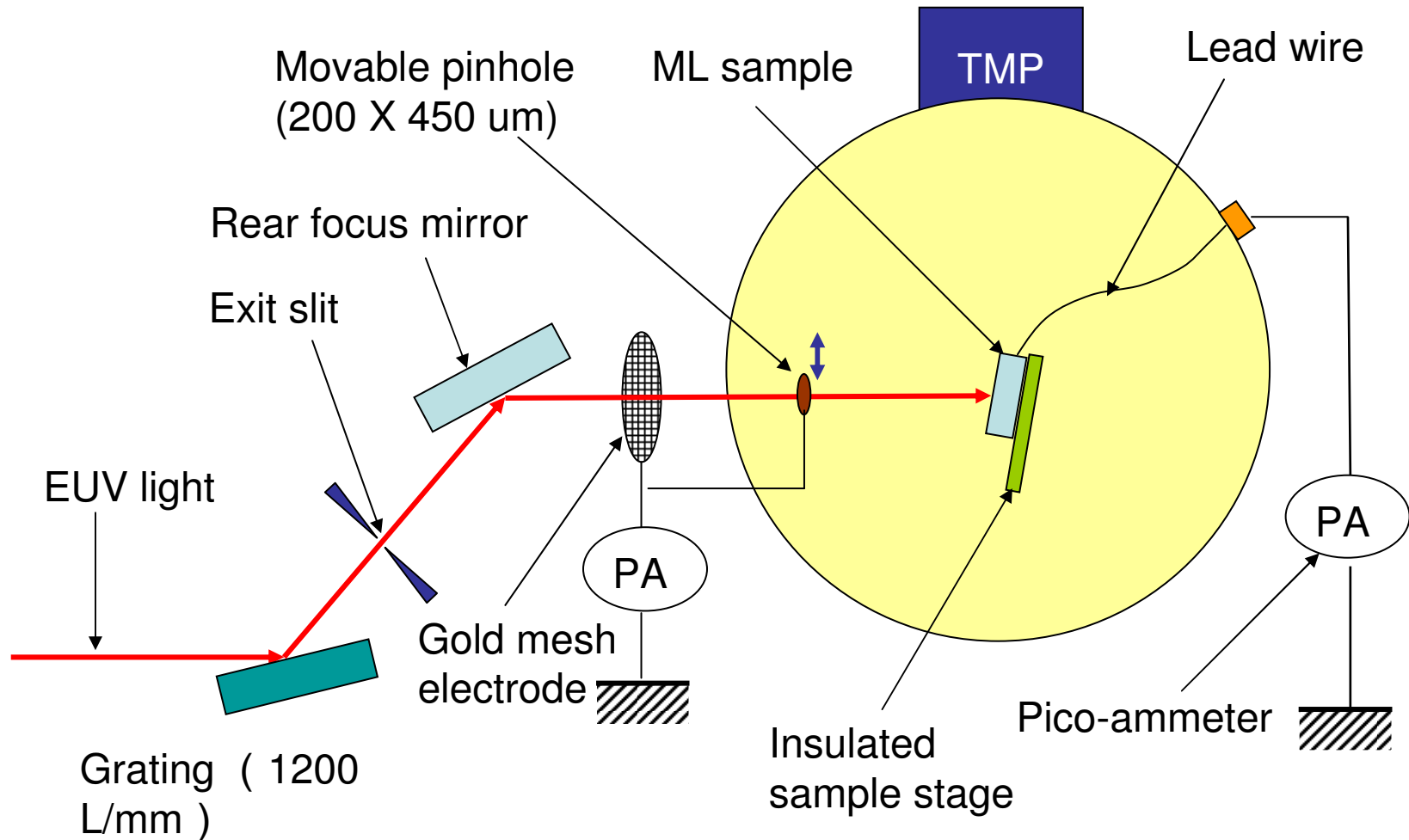


The reflectometry was successfully carried out.



In situ XANES measurement system

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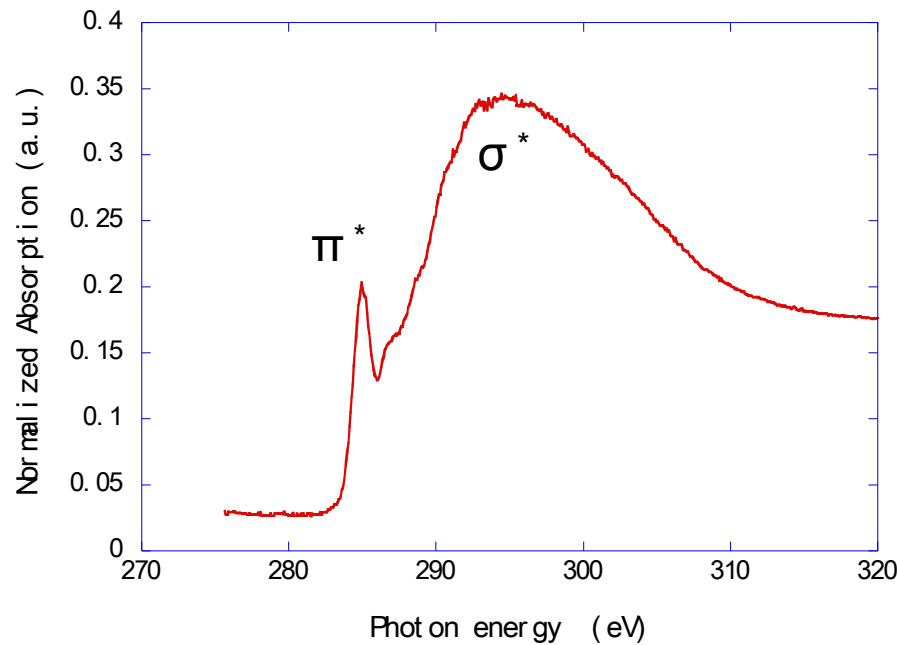


Total electron yield (TEY) mode by recording the photocurrent from the sample

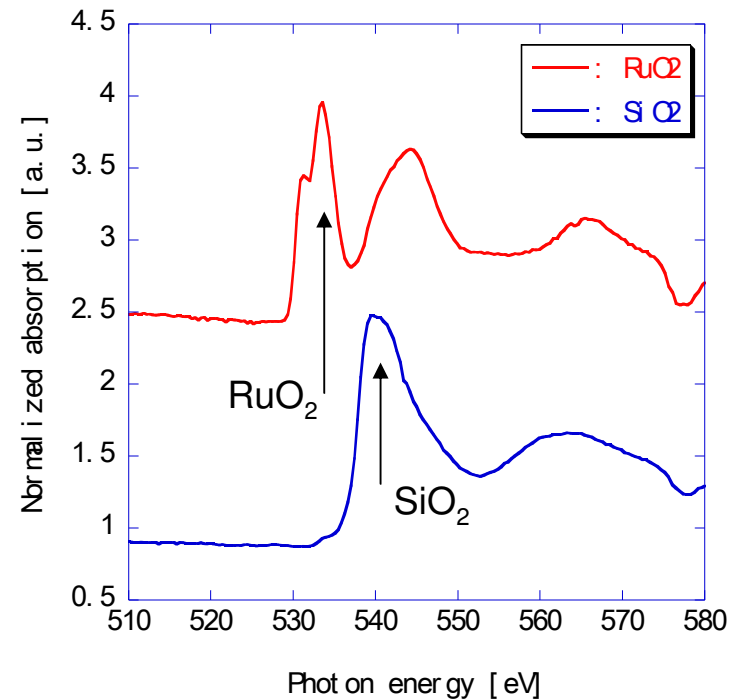


XANES Spectra of C and O K-edge

- The shapes of XANES spectra are fairly good and very similar to those reported in literature.



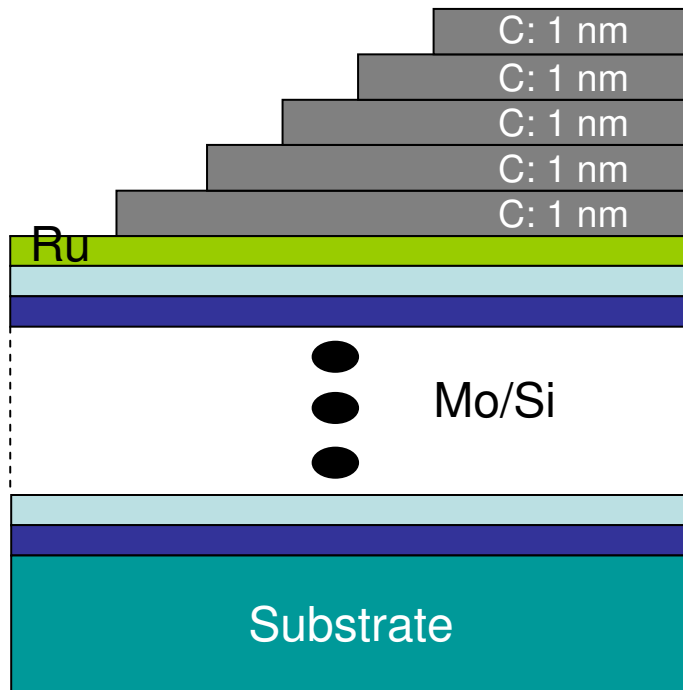
C K-edge absorption of contaminated carbon film



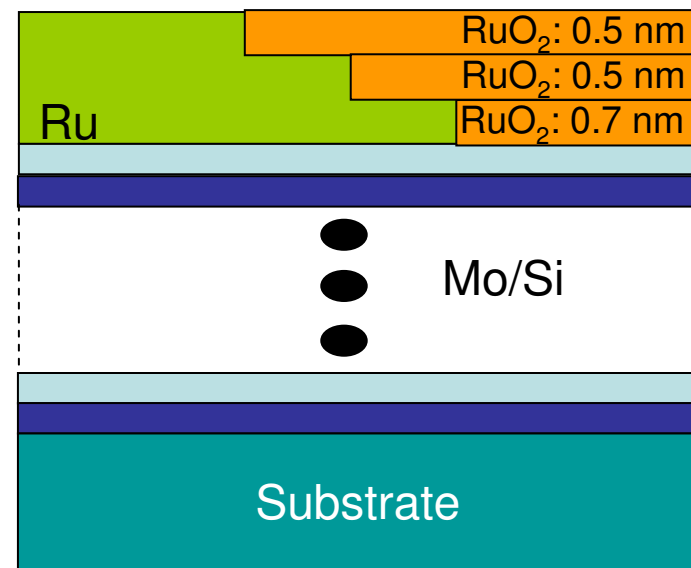
O K-edge absorption of RuO₂ and SiO₂ films



Standard samples for XANES calibration



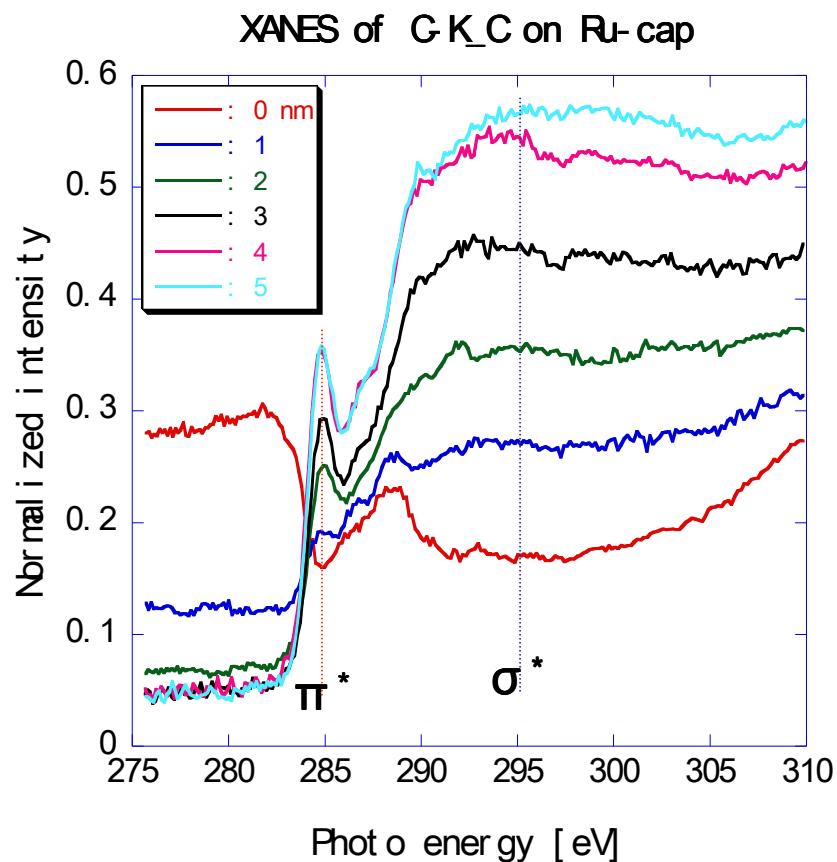
Standard samples for carbon deposition



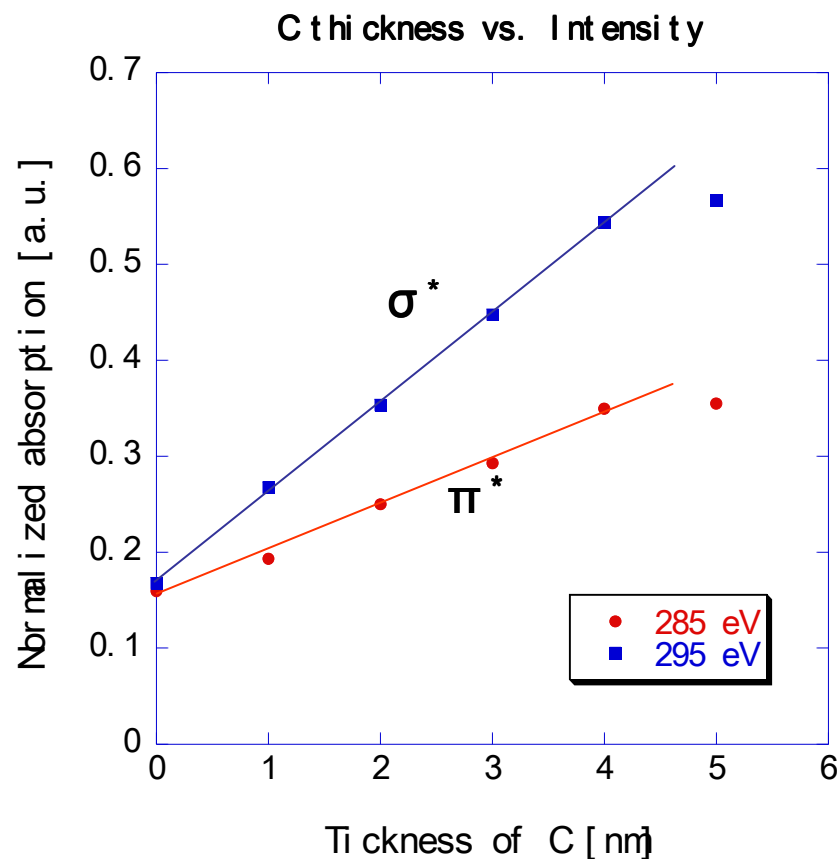
Standard samples for surface oxidation



Working curves of C-K absorption intensity vs. C film thickness 8



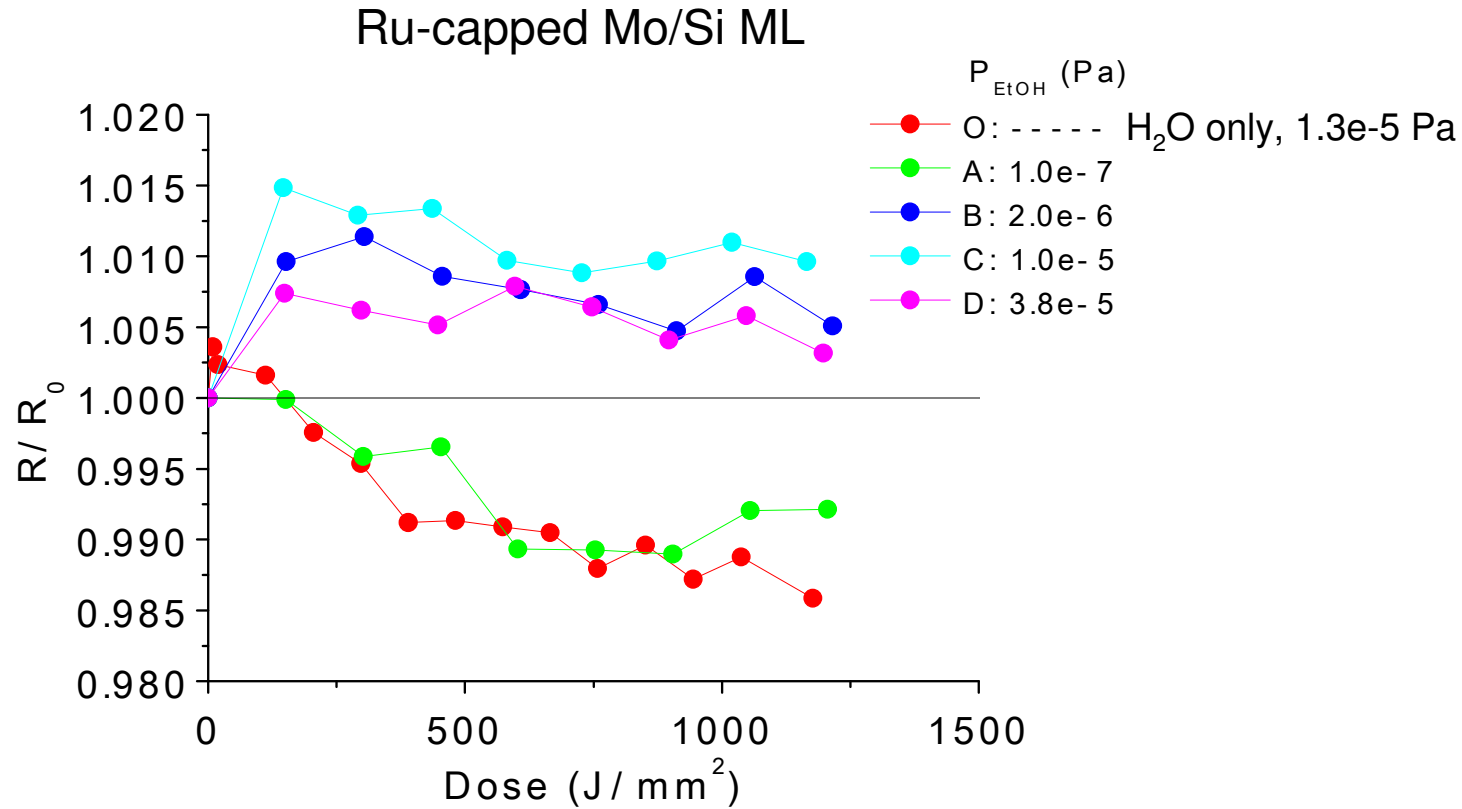
C-K XANES spectra of standard C films deposited on a multilayer



Working curves of C-K edge absorption intensity



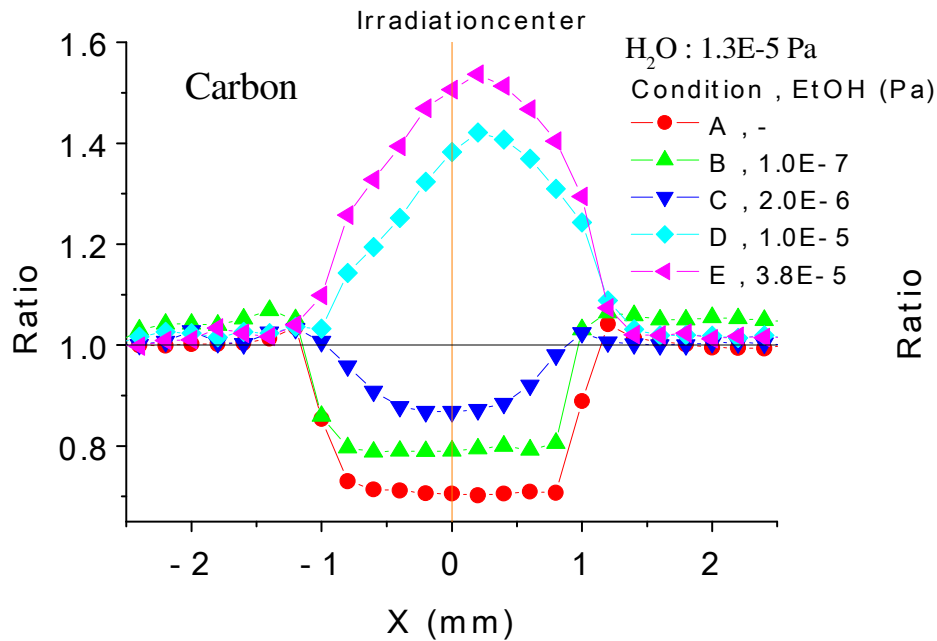
Reflectivity change of EtOH introduced experiment



Sequential measurement of reflectivity change by EUV Irradiation in various EtOH pressure condition

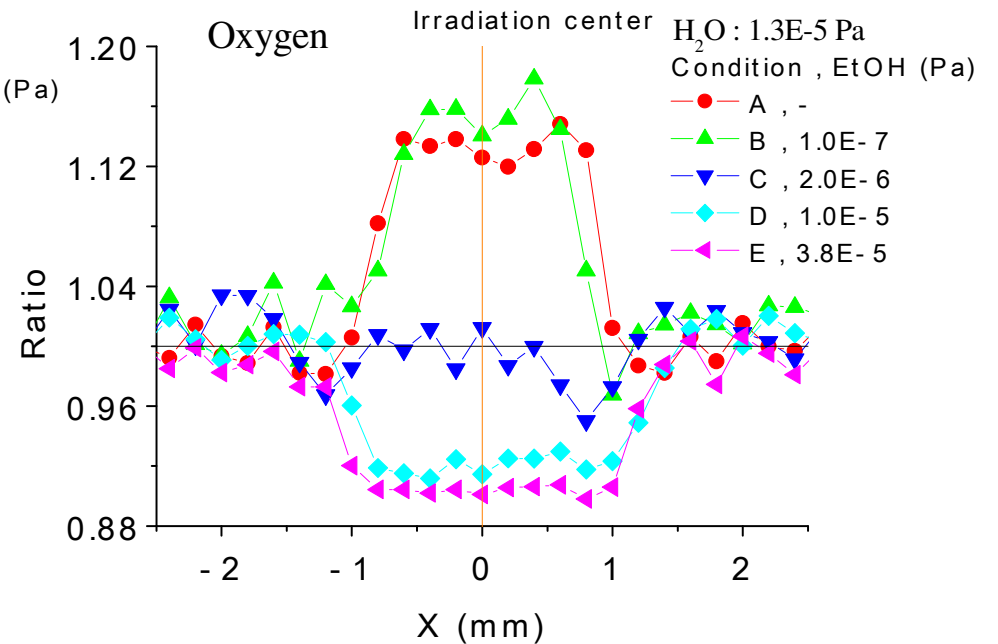


Ratio { I (292 eV) / I (282 eV)}



Concentration map of Carbon at the EUV irradiation area

Ratio { I (533 eV) / I (517 eV)}

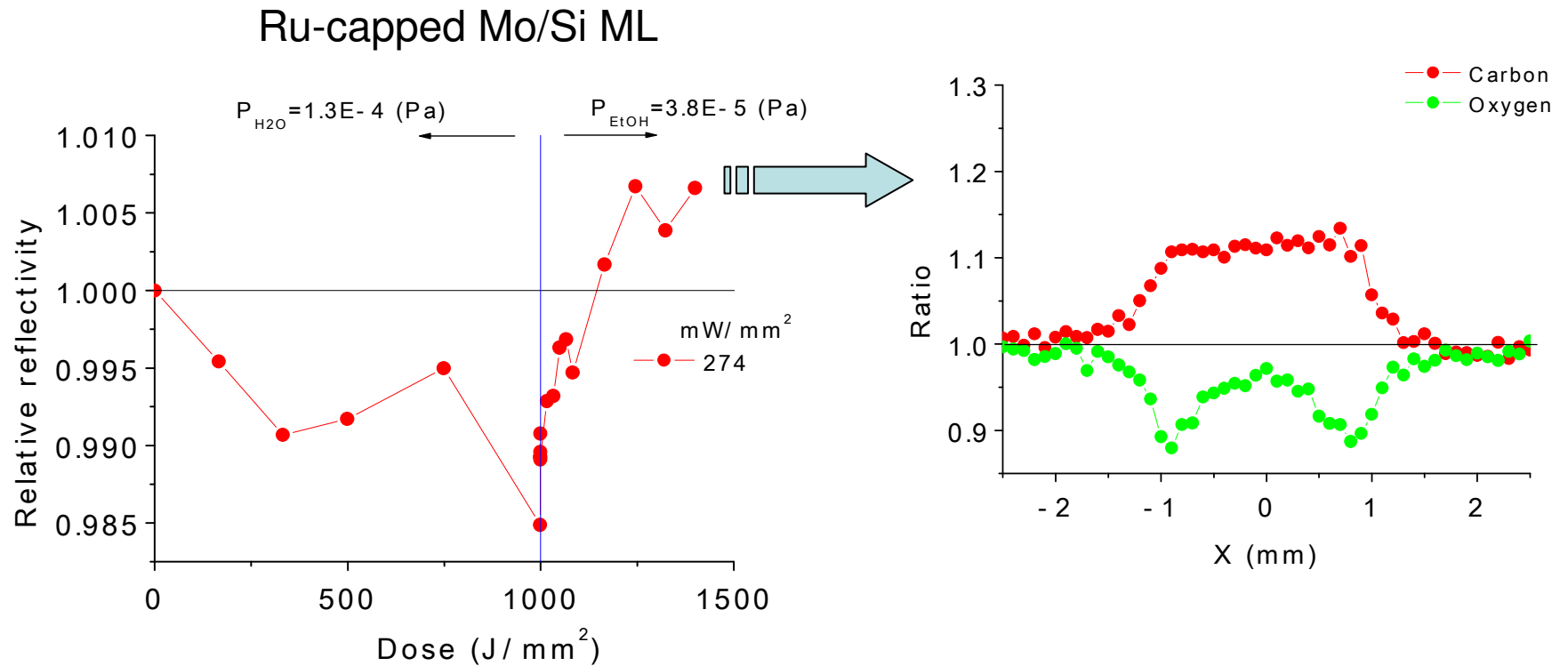


Concentration map of Oxygen at the EUV irradiation area



- The result indicates that reactions of carbon deposition and surface oxidation occur **simultaneously and competitively**.





RuO₂ can be reduced to Ru metal by EUV irradiation in the presence of EtOH vapor.



1. Contamination evaluation system was developed in the NewSUBARU SR facility, in which *in situ* surface analysis and elemental concentration mapping was carried out by *in situ* XANES method.
2. The linearity of XANES intensity and contamination thickness was confirmed by the examine of standard samples.
3. Applying the in situ XANES analysis to the experiment of EtOH introduction in vacuum atmosphere, we can get very important information to protect the surface of EUVL optics.



Off-line XPS analysis of the same (EtOH) samples

| EtOH (Pa) | O (%) | C (%) | Mo (%) | Si (%) | Ru(3d) |
|-----------|-------|-------|--------|--------|--------|
| 3.8 e-5 | 27.7 | 41.6 | 0.5 | 8.2 | 18.5 |
| 1.0 e-5 | 28.2 | 42.1 | 0.5 | 10.6 | 18.6 |
| 2.0 e-6 | 36.9 | 24.2 | 0.6 | 13.1 | 25.1 |
| 1.0 e-7 | 42.8 | 24.4 | 0.6 | 11.0 | 21.3 |
| none | 42.2 | 19.7 | 0.7 | 12.5 | 24.9 |
| Ref. | 35.3 | 35.3 | 0.5 | 9.9 | 19.1 |

| EtOH (Pa) | SiOx/(SiOx+Si) | RuOx/(RuOx+Si) |
|-----------|----------------|----------------|
| 3.8 e-5 | 60.5 (%) | 25.9 (%) |
| 1.0 e-5 | 62.9 | 25.6 |
| 2.0 e-6 | 65.2 | 33.1 |
| 1.0 e-7 | 64.2 | 60.6 |
| none | 64.2 | 52.2 |
| Ref. | 61.6 | 42.8 |

The results of in situ XANES analysis are qualitatively consistent with those of off-line XPS.

