In situ XANES Analysis for EUVL Projection Optics Contamination

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Extreme ultraviolet lithography (EUVL) is a leading candidate for the manufacture of next-generation semiconductor devices later this decade. It is strongly demanded to protect the surface of the lithographic optics from contamination and degradation in order to constantly maintain the throughput of the EUVL equipment. To investigate EUVL projection 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. An in situ X-ray absorption near edge structure (XANES) spectrometry technique was developed and used in our contamination study in which surface state analysis and element concentration mapping were carried out.

A contamination evaluation system was installed at the end-station of the long-undulator beamline (BL9) in the NewSUBARU SR facility. Figure 1 shows the schematic diagram of our contamination evaluation system. In the BL9, a high-resolution soft-X-ray monochromator has been equipped, and monochromated radiation beam has been utilized at the end-station. Total electron yield (TEY) spectrum of photoemission by X-ray absorption was obtained with scanning the photon energy. The size of the monochromated beam was 0.25(h) x 0.45(v) mm^2 at the sample surface. By scanning the

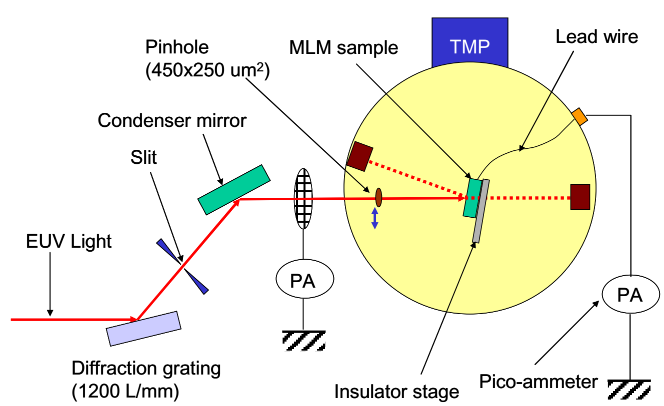

Fig. 1 Schematic diagram of the contamination evaluation system.

sample two-dimensionally and collecting the TEY data, an elemental concentration map was obtained around the irradiated area. Working curves of absorption intensity of π*(285 eV) and σ*(295 eV) resonance absorption of C-K edge vs. carbon film thickness, which were measured from the standard samples of film thickness of 0.0 nm to 5.0 nm, are shown in Fig. 2. The linearity of the working curves are fairly good to 4.0 nm film thickness.

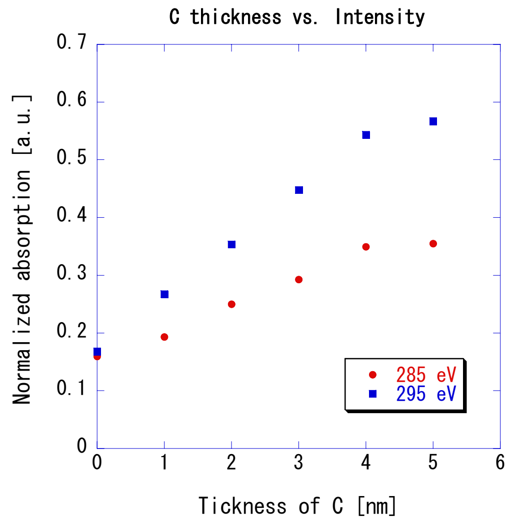

Fig. 2 Working curves of absorption intensity vs. carbon film thickness.

As an example of the XANES analysis application to the contamination study, in situ observation of oxidation inhibition effect of ethanol (EtOH) introduction into the vacuum chamber was carried out for Ru-capped Mo/Si multilayer. The reflectivity of the multilayer decreases gradually when the EUV flux density of 150 mW/mm^2 was irradiated on the multilayer sample under the water vapor pressure of 1.3E-5 (Pa). The reflectivity drop was inhibited when the EtOH vapor of more than 2.0E-6 (Pa) was introduced into the chamber in addition to the same water vapor condition.

One-dimensional element concentration maps of carbon, C, and oxygen, O, in the vicinity of EUV irradiated area are shown in Fig. 3(a) and (b), respectively. As a result of XANES analysis, it is found that neither oxidation nor carbonaceous film deposition was occurred on the surface of Ru-capping layer under the ethanol vapor condition of 2.0E-6 (Pa). The in situ XANES analysis is a simple and useful technique to understand the optics contamination phenomena.

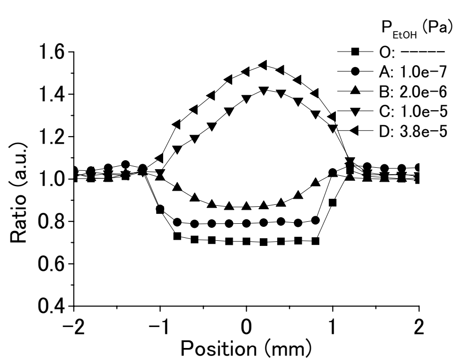

Fig. 3(a) One-dimensional element concentration map of C in the vicinity of EUV irradiated area.

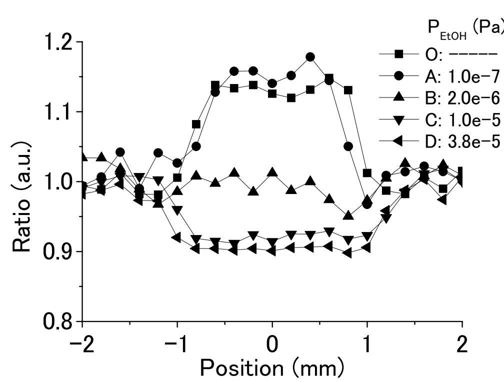

Fig. 3(b) One-dimensional element concentration map of O in the vicinity of EUV irradiated area.