§29. A proposal of In-situ Diagnostics Methods for PFMs under Multiple Irradiation

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The diagnostics of plasma facing materials (PFMs) is a primary issue for maintenance of the high performance plasma in fusion devices. In order to evaluate PFMs conditions which alternate continually during long duration discharges, in-situ and real-time diagnostic methods of PFMs are highly desired as an alternative to the existing postmortem methods. In this study, optical reflectivity measurement is proposed as a convenient in-situ diagnostics of the radiation induced microstructure change and its applicability is evaluated.

The material probe experiments were performed using the samples exposed to LHD plasma during the 15th and 16th experimental campaigns, taking into account adaptation to in-situ diagnostic. The probe samples and their installation positions are shown in Fig. 1. The optical reflectivities for mirror polished W and stainless steel (SUS316L) probes were examined with a spectroscopic ellipsometer and FT-IR. In-situ measurements of the reflectivity change under the irradiation with 1-5 keV deuterium and helium ions were also performed for comparison. In addition to the reflectivity measurements, corresponding modification of the microstructure induced by the plasma exposure and the ion irradiations was also examined with SEM and TEM. FIB technique was applied to make the specimen ready for cross-sectional observation.

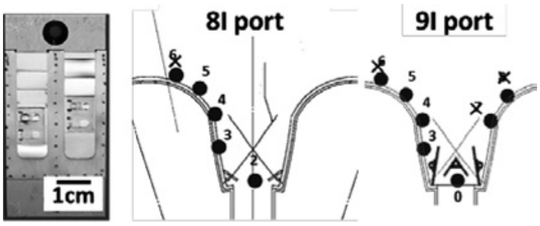

Fig. 1. The material probes exposed to LHD plasma and the installation positions.

The significant degradation of the reflectivity for the samples exposed to LHD plasma was detected and the level of the degradation depended on the location, exposure period and employing wavelength. TEM observation revealed the radiation damages and the depositions consisted of mainly carbon on these samples. Fig. 2 (a) shows an example of cross-sectional microstructure images. These samples indicated the discriminative reflectivity spectra depending on the deposition thickness formed on the samples as shown in Fig. 2 (b). Especially, a proportionality relation between the wave length at which the reflectivity has a local minimum value and the deposition thickness was observed (Fig. 2 (c)). On the other hand, the reflectivity for erosion dominant samples showed similar tendency to that for the sample irradiated with helium ions, and helium bubbles seemed to play important role on degradation of the reflectivity. In addition, a simpler method using a color analyzer was suggested and applied for an analysis the probe samples. It was implied that the method had an availability as diagnostics for a thin deposition layer within ~50nm. As a result, the optical reflectivity measurement is considered to be a possible method for convenient in-situ diagnostics for PFMs.

In this study, the crystal orientation dependence on the reflectivity and the gas retention property as well as a surface damage was also investigated using with single crystal samples with various orientations under the ion irradiation. A remarkable dependence depending on the orientation was observed, and the control of the crystal orientation seems to be effective for a suppression of damages and keeping reflectivity. As next step experiments, in-situ measurements of reflectivity at wide wavelength will be performed with a supercontinuum white laser covering a broad spectral range from 450nm to 2000nm. For the purpose of applying the reflectivity measurement to diagnostics in LHD, we plan to optimize the method to obtain the information of the wall condition as necessary for LHD plasma operation.

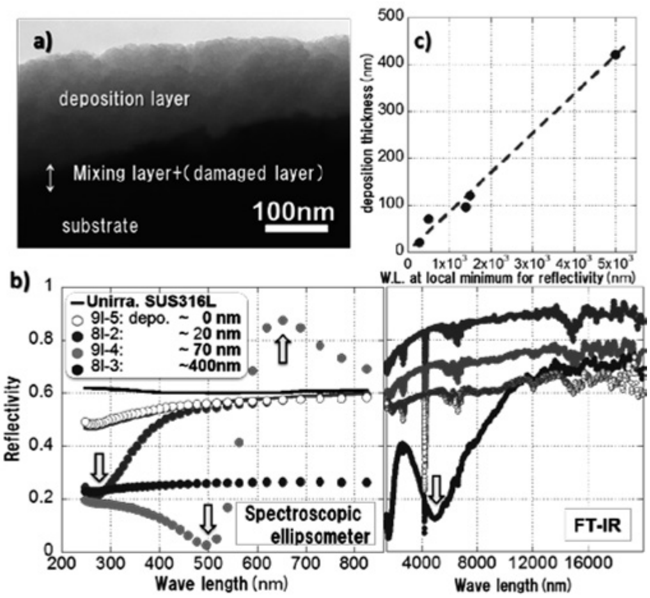

Fig.2 A cross-sectional microstructure (a) and the reflectivity spectra in the SUS sample exposed to LHD plasma (b). A strong correlation between the reflectivity and the thickness was observed (c).