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In-situ measurement of reflectance spectra in metal mirrors irradiated with low energy He ions
低エネルギーヘリウムイオン照射下における金属ミラー材の
反射率スペクトルのその場測定

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Optical reflectivity measurement has been proposed as a convenient diagnostics method of surface modifications in plasma facing materials. In this study, in-situ measurement of reflectance spectra is applied for more accurate diagnosis by using a super-continuum laser with a broad wavelength range. The wavelength dependence of reflectivity for mirror polished metal samples irradiated with helium ions which causes significant damage to metal is examined as functions of ion energy and fluencce.

1. Introduction

In a future nuclear fusion reactor, the understanding of surface properties change of plasma facing materials (PMFs) is one of the most important issues from the viewpoint of steady state operations. In order to evaluate PFMs conditions, therefore, in-situ and real-time diagnostic methods of PFMs are highly desired as an alternative to the existing postmortem methods.

In our recent study, optical reflectivity measurement were proposed as a convenient diagnostics method of surface modifications in PFMs and the real-time change of the optical reflectivity for the metal mirror samples under the irradiation with low energy helium (He) and deuterium (D) ions [1-3]. Since the detectable reduction of the reflectivity was clearly observed, the optical reflectivity measurement is considered to be a possible diagnostics method. In this study, in-situ measurement of reflectance spectra is proposed as a more accurate diagnostics of the radiation induced microstructure change by using a super-continuum laser with a broad wavelength range and its applicability is discussed.

2. Experimental

Specimens used in the present study were made from base materials of solute annealed type 316L stainless steels. The specimens were cut into plates of a size of 10×10×0.5 mm^3 and mirror-polished mechanically with 50 nm alumina powder. The specimens were irradiated with 1, 3 and 5 keV helium ions at room temperature, respectively, up to a fluence of about 1×10^{23} He/m^2. Irradiation was performed with a newly built device for the present study. This device enabled in-situ measurements of the change of reflectance spectrum during irradiation with a flux of 5×10^{17} He^+/m^2s. The reflectance spectrum under the irradiation was measured with a super-continuum laser and a spectrometer, which were placed at an angle of 45° from the normal direction on the specimen surface. The reflectance of a wavelength from 190 to 1100 nm was measured in real time. In addition to the reflectance measurement, the microstructure evolution induced by irradiation was examined by SEM and TEM to obtain the information about the correlation with the reflectance spectrum.

3. Results

The reflectance spectra were obtained under the He^+ irradiation. Fig. 1 shows the typical data of the wavelength dependences of the reflected light for SUS316L irradiated with He^+ ions at several fluences. The sufficiently detectable change of the intensity was observed and the level of the degradation depended on wavelength. Fig. 2 shows the normalized reflectivity of SUS316L irradiated with 3 keV He^+ ions at room temperature as a function of fluence. The reflectivity decreased with the fluence almost monotonically, and the reflectivity fell to less than 40 % at a fluence of

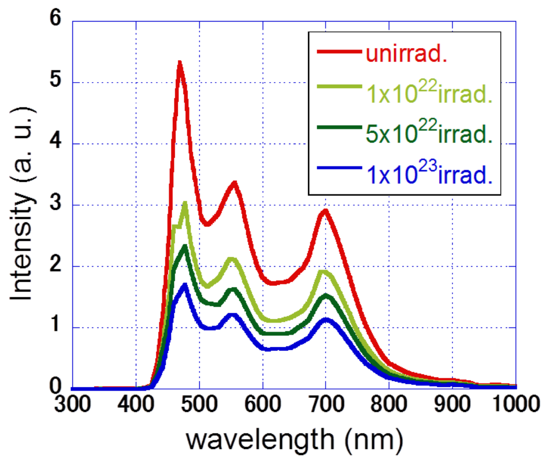

Fig.1. The dependences of intensity of reflected light on the wavelength in SUS316L irradiated with He^+ ions.

$1{\times}10^{23}$ He/m^2. The dependence of the reflectivity on the wavelength shows a tendency that larger reduction occurred in the shorter wavelength region. Since the penetration depth of the incident light depends on the wavelength, the correlation between the depth profile of defects and the penetration depth can be pointes out.

In a case of higher energy irradiation of 5 keV He^+ to SUS316L, peculiar behavior of reflectivity change was observed as shown in Fig. 3. It should be noted that the reflectivity fluctuate as to fluence. A local flaking or exfoliation of the damaged layer is one of the possible mechanisms for the apparent recovery and oscillation of the reflectivity, because the reflectivity is strongly affected by radiation damages in the sub-surface

As a result, the measurement of reflectance spectra is considered to be a possible method with high accuracy for in-situ diagnostics for PFWs.

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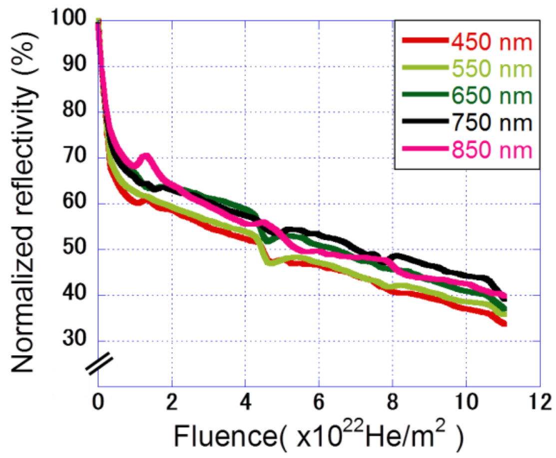

Fig.2. The reflectivity change in SUS316L irradiated with 3 keV He^+ ions as a function of fluence.

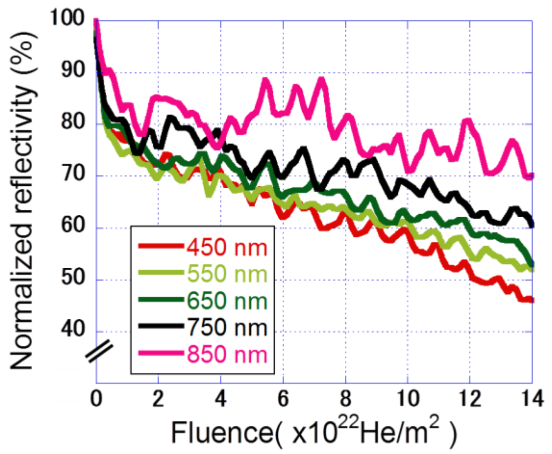

Fig.3. The reflectivity change in SUS316L irradiated with 5 keV He^+ ions as a function of fluence.

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