§31. Degradation of Optical Reflectivity of In-vessel Mirror Materials by Helium Bombardment

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Many in-vessel mirrors will be used in ITER for optical diagnostics, i.e., spectroscopy and laser diagnostics. For the first mirrors, several materials including molybdenum, tungsten, and rhodium are regarded as candidate materials. However, several problems remain for the final selection of the materials, and further investigations are required. In this study, we investigate the helium irradiation effects experimentally at the surface temperature range of 500-700 K, which corresponds to the expected operational temperature of the first mirrors. Changes in the optical reflectivity and surface morphology of Mo by helium irradiation are investigated in detail.

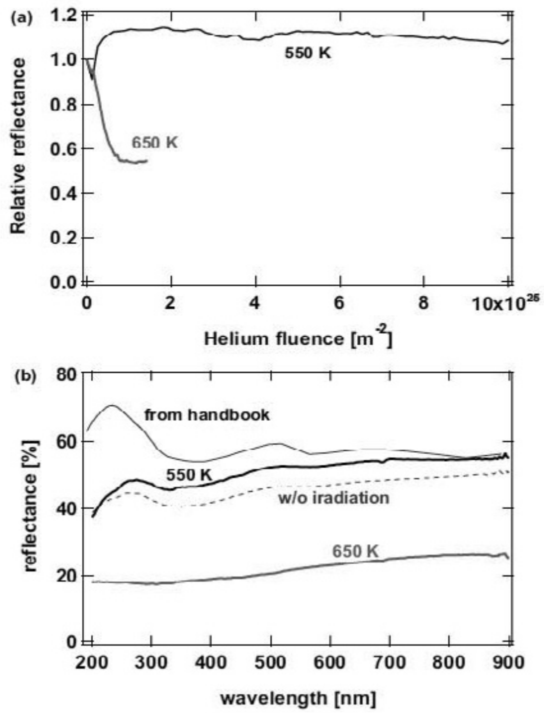
Experiments were performed in the linear plasma device NAGDIS-I. A specimens was equipped on a water-cooled stage and electrically biased to approximately -50 V with respect to the space potential. A specular optical reflectance was measured during the irradiation using a He-Ne laser and a detector. The wavelength dependence of the reflectance from 250 to 900 nm was measured using a spectro-photometer (Nihon Bunkosya: ARV-47S) after the irradiation.

Fig. 1 (a) shows a temporal evolution of the relative optical reflectance at 633 nm at two different surface temperatures, i.e. 550 K and 650 K. When the surface temperature was 650 K, the reflectance decreased with the helium fluence, and approximately 60% of the initial value at the helium fluence of ~1×10^{25} m^{-2}. On the other hand, when the surface temperature was 550 K, the surface reflectance increased initially and was higher than the initial value even at the helium fluence of >1×10^{26} m^{-2}. The result indicates that the difference of the surface temperature in this temperature range has a crucial effect to the surface reflectance.

Fig. 1(b) shows the wavelength dependence of the optical reflectance of Mo samples without and with the exposure to the plasma. The reduction in optical reflectance appeared even for Mo at the surface temperature of 650 K. Interestingly, however, there was no reduction in optical reflectivity at 550 K.

Fig. 2(a) and (b) show the SEM (scanning electron microscope) micrographs of the helium irradiated molybdenum surfaces at the surface temperature of 650 and 550 K , respectively. Fig. 2 (c) and (d) are the AFM images of the molybdenum surfaces. The surface became very rough when the helium was exposed at 650 K. Pin-holes were observed on the surface, and the roughness was probably caused by the formation of helium bubbles on the surface. On the other hand, when the surface temperature was 550 K, there were no significant modifications by the helium irradiation. Although small nanobubbles might have been formed on the surface, it is so small that they can not contribute to the surface roughness that can be observed by SEM and AFM.

It can be said that the surface temperature is a key parameter to control the helium irradiation, and sufficient cooling is necessary for the first mirrors.



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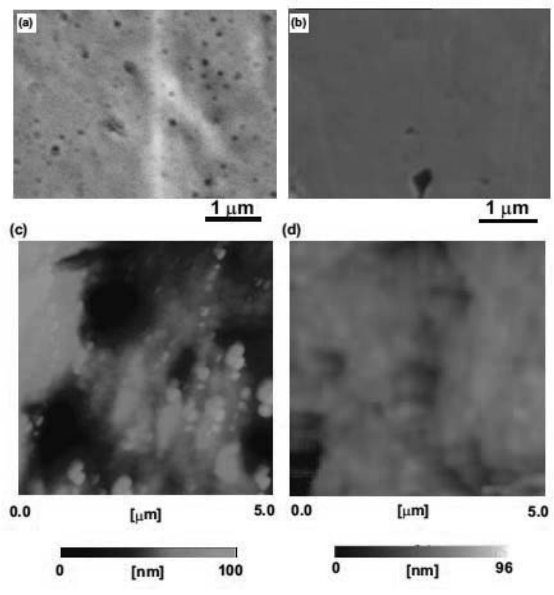

Fig. 2. SEM and AFM micrographs of the helium irradiated molybdenum surfaces.