§11. Investigation of the Physical Properties of the Mixed-material Deposition Layer Formed on the First Wall Surface of the LHD

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The Large helical device (LHD) has an important advantage for steady state operation (SSO). First wall panels and divertor plates of LHD are stainless steel (SUS316L) and graphite, respectively. The former is the major material in LHD, and the graphite area is only about 5% of the total plasma facing area. The temperature of the first wall is almost kept at room temperature (R.T.) during plasma discharges. For establishment of the SSO plasma, there are some problems related to the plasma wall interactions (PWI). In the recent SSO experiment, a high-performance ultra-long pulse helium discharge of 48 min with n_e ~1.2×10^{19} m-3, $T_{i,e}$ ~2 keV was successfully achieved by the higher heating power of 1.2 MW. By using such high performance plasmas, PWI studies for SSO has been accelerated. However, it was revealed that particle balance of the helium was difficult to control after about 5 or 10 min elapsed due to the desorption of the helium from the wall surface. On the other hand, sudden increase of the C and Fe emissions in plasma due to the mixing of the impurities from the wall surface disturbed and terminated the SSO plasmas. Although the first objective on this research was supposed to investigate the hydrogen retention properties on the plasmas facing surface of the LHD, helium retention properties were also focused on. And also, since the undesired mixing of the C and Fe impurities likely due to the exfoliation of the mixed-material deposition layers formed on the first wall surface and divertor tile's surface [1-2], microscopic analysis of the mixed-material deposition layers was also conducted by using the accelerator of Nagoya University. The Si sample which exposed to the 14th LHD plasma experiment was determined as an analyzing sample of this experiment.

The Si substrate was mounted on the first-wall surface of near the 3O (outer) port area of the LHD, and then, exposed to the single experimental campaign of 14th plasma experiment. After the exposure, the Si substrate was extracted and was transferred to the Nagoya University. Rutherford backscattering spectrometry (was) analysis was carried out by using the Van de Graaff type accelerator. An analyzing beam was selected as a 1.8 MeV-He^+ with 160 degree scattering angle.

The RBS spectrum from the Si substrate was shown in Fig. 1. The horizontal axis is a channel number of the multi-channel analyzer of the RBS detector, and the vertical axis is a number of the counts of the backscattered He atoms. The detected elements were Fe, Mo, W, O, C, and Ti. Table 1 shows the amount of the included elements in the deposition layer. We can know that the majority of the composed elements were C, Fe, and O from Table 1. The RBS spectrum and Table 1 indicate that the deposition layer was the mixed-material deposition layer of these elements. It is considered that the C was mainly deposited during the main plasma discharges due to the sputtering erosion of the carbon divertor tiles. On the other hand, Fe elements were likely deposited during the glow discharge cleaning due to the sputtering erosion of the first-wall surface [3]. The certain amount of the Oxygen which existed in the vacuum vessel was also deposited together with C and Fe.

Due to the PWI, the mixed-material deposition layer including C, Fe, and O seems to be continuously formed. The grown thick deposited layer likely to exfoliate, and then, mixed into the plasma. Such phenomenon is a large problem for maintaining the steady-state plasma discharges in LHD. If we would want to suppress of the formation of the thick mixed-material deposition layer, the deposition layer should be eliminated repeatedly before growing the critical thickness of the exfoliation. On the other hand, using a low-sputtering yields element might be the better way for controlling the formation of the mixed-material deposition layers.

1) M. Tokitani et al., J. Nucl. Mater. 417 (2011) 668-672
2) M. Tokitani et al., J. Nucl. Mater. 438 (2013) S818-S821
3) M. Tokitani et al., Nucl. Fusion 45 (2005) 1544-1549

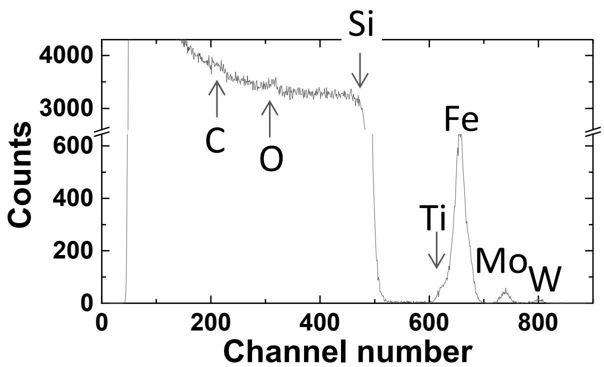

Fig. 1. The RBS spectrum from the mixed-material deposition layer formed on the Si substrate which exposed to the 14th LHD plasma experiment.

	Fe	Mo	W	O	C	Ti
amount (×10^{19}atoms/m^2)	33.4	0.60	0.060	49	58	3.0

Table 1. Amount of the included elements in the mixed-material deposition layer formed on the Si substrate.