§29. Profiles of the Surface Morphologies on the LHD First-wall by Using Toroidal Array Probes

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The first-wall panels and divertor plates on LHD are composed by SUS316L and graphite, respectively. Their structures are quite complicated due to the 3D-helical configurations. Evaluation of the toroidal profiles of the microscopic damage and erosion/deposition on their surface is important for not only material assessment but also plasma operations. In this study, 10 pairs of SUS316L and Si specimens were mounted on the 10 sets of the special specimen holder, and were located on the outer-side of the first-wall surface in each 36º toroidal angle section (No.1~10). Their holders were composed of two types, "floating-potential" and "ground-potential", in one toroidal section for separating the effects of the GDCs and main plasma discharges. In former type, they were electrically insulated from first-wall, so energetic ions during GDCs would not be able to be injected into the specimens. Therefore, we could analyze the two cases which were exposed with or without GDCs. Ne, He and H_2 were used as working-gases for GDCs. After the exposure, microscopic damage, erosion/deposition profiles and hydrogen retention properties were examined by using transmission electron microscopy (TEM) and Rutherford backscattering spectroscopy (RBS) analysis.

Fig. 1 shows the RBS spectra of the ground and the floating Si specimens at the No.1 section. In the case of the floating, thick deposits composed by Fe, C and O were formed on the surface. The thickness of the deposition layer was 500 nm by using cross sectional TEM analysis. While, very thin Fe deposition layer co-deposits with O with the thickness of about 50 nm was identified on the surface. This means that sputtering erosion of the first-wall surfaces was mainly caused by not main plasma discharges but GDCs, and deposited impurities during main plasma discharges could be mostly sputtered by GDSs phase. Fig. 2 shows the erosion depth of the SUS 316L ground specimens at each toroidal section by using atomic force microscopy (AFM). The erosion depths were not uniform along the toroidal direction with the deviation between 100 and 1000 nm.

In addition, we tried to clarify the dependence of the toroidal section of the microstructure change in SUS316L specimens due to the exposure to energetic particles by using cross-sectional TEM analysis. Fig. 3 shows the comparison of the (a) No.1 and (b) No.3 toroidal section. In the case of the No.1 section, thin deposition layer including small amount of Fe with the thickness of about 50nm which corresponds to the RBS spectrum of Fig. 1 was identified on the surface, and, any radiation damages on the SUS316L matrix were not showed. While, there was completely no deposition on the surface of the No.3 specimen, but, very dense helium-bubbles with size of 1-5nm were observed on sub-surface region. These damages were caused during both GDCs and main plasma discharges. One should note that formation of the microscopic damages has a strong positional dependence at toroidal section. In addition, once the surface was covered with some deposits, any energetic particles, GDCs plasma or charge-exchanged neutral particles (CX-neutrals) cannot be injected into the matrix. It may be one of the possible protection systems for the plasma facing walls in fusion machines.

These results indicates that GDCs act as the main role for cleaning the first wall surface for whole toroidal sections, but the erosion and deposition profiles were different with each section. Especially, radiation damages caused by helium irradiations were serious on the erosion dominant surfaces. The operation scenario of wall conditioning should be considered separately in each toroidal section.

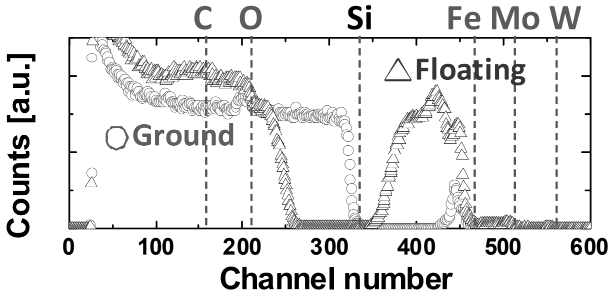

Fig. 1. RBS spectra of ground and floating Si specimens at No.1 section.

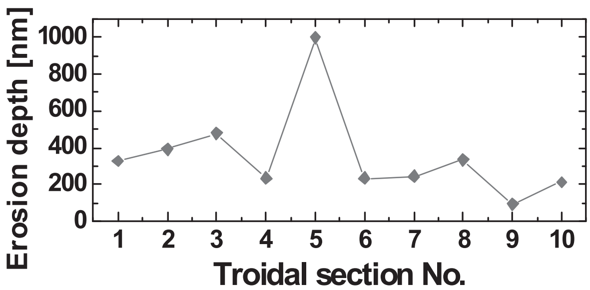

Fig. 2. Erosion depth of the SUS316L ground specimens at each toroidal section.

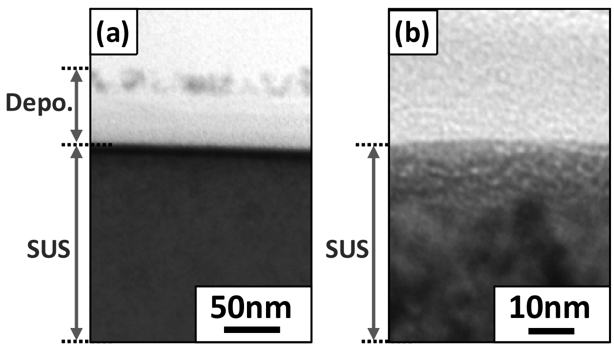

Fig. 3. Cross-sectional TEM image of ground SUS316L specimens at (a) No.1 and (b) No.3 toroidal section.