§13. Surface Morphology of Helium Plasma Exposed Tungsten

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Tungsten is a primal candidate for a plasma facing materials (PFM) in fusion reactor due to the excellent high temperature properties, high sputtering threshold energy, low hydrogen retention and acceptable induced radioactivity. From the view point of the LHD experiments, usage of tungsten have advantages of reduction of carbon flake generation which obstructs long-pulse discharge, and reduction of hydrogen isotope retention in PFM. However, bulk tungsten is too heavy to use as a PFM in the vacuum vessel of LHD. Probably, thin tungsten coated carbon plate is only possible solution to use tungsten PFM in LHD, although it is concerned about the lifetime of the thin tungsten coating layer.

Helium gas is used frequently in addition to hydrogen isotope gases in the LHD experiments. There are many experimental results which indicate the strong effect of the helium irradiation on the surface morphology of tungsten, e.g. nano-bubble, hole and fuzz nanostructure. Furthermore, previous researches have shown that hydrogen isotope retention is significantly affected by helium distribution in tungsten surface layer. These result emphasize the importance of helium effects on tungsten as a PFM. In order to simulate tungsten behavior under the heavy helium plasma exposure conditions, helium plasma exposure experiments have been carried out in the linear plasma device PSI-2.

Under the heavy exposure conditions at fluence of 1.0×10^{26} /m^2, significant surface morphology is observed. An undulating surface structures (Fig. 1) are formed at low temperature below 1073 K, and the fuzz structure is formed at 1573 K. The fuzz structure is commonly observed at the temperature range between 1000 K and 2000 K as reported in many previous studies, however the temperature range of the fuzz formation is rather high as compared to envisioned PFM temperature of LHD. Therefore, the undulating surface structures are worth noting. Direction and interval of the undulating surface structures vary by the crystal grain and the undulating surface structure can be broken down into the four patterns as shown in Fig. 1. This fact suggests that the crystal orientation might be an important factor in the undulating surface structure development. In order to obtain a crystal orientation of the each grain, Electron backscattered diffraction pattern analysis (EBSD) has been employed. The comparison between the SEM and EBSD analyses shows that the narrow interval grain (Fig. 1 (a)) shows strong correlation with the {110} plane. The undulating surface structure align with <100> direction which is located on the surface. As a grain surface tilt from {110} plane, interval of the undulating surface structure becomes wider as shown in Fig. 1 (b). When two <100> directions equally close to the grain surface, the edge of the undulation becomes jaggy as shown in Fig. 1 (c), and then any surface structure cannot develop when no <100> direction close to the grain surface

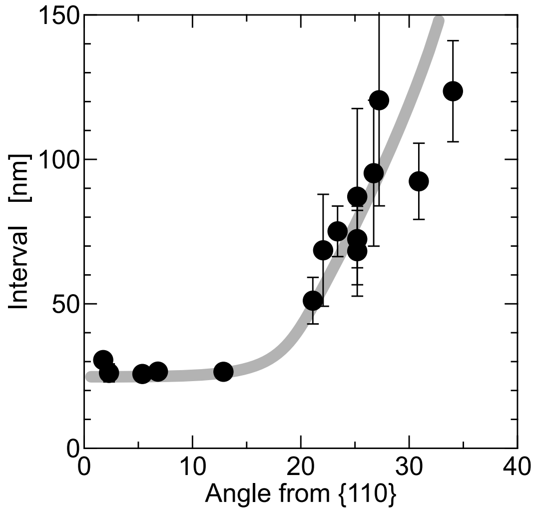

Fig. 2: Crystal orientation dependence of the undulation interval.

Significant surface modifications is observed and the modification have a potential to enhance a surface erosion despite that the energy of incident helium particles are below the threshold energy of sputtering. In order to estimate a lifetime of the thin tungsten coating layer, it is important to understand the surface morphology of helium plasma exposed tungsten.

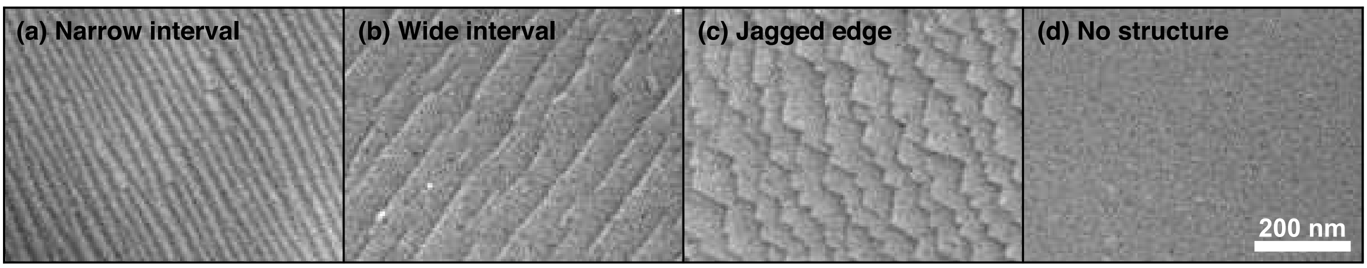

Fig. 1: Four typical types of the undulating surface structures.