§8. Change of Surface Properties of First Wall due to Installation of Closed Divertors

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Control of retention and desorption of plasma particles through the plasma facing surfaces based on the fundamental understanding of the phenomena is one of important key issues to establish steady-state operation. Science Cycle 12, 2008, we have continually placed many kinds of metallic samples on the inner protection wall near 8I and 9I ports to probe the change of the surface properties and its influence on retention and desorption of plasma particles. Characteristic modifications of surface properties of tungsten and stainless steel (SUS316L, material for the protection wall of LHD) exposed to LHD plasmas through each experimental campaign are summarized as followings.

First of all, microstructure at subsurface region is heavily modified by the glow discharge cleaning (GDC) with Ne, He, and H. Though GDC effectively removed deposited impurities and oxide on the plasma-facing surfaces, the sub-surface region of about 10nm-thick was heavily modified; namely, the layer consists of elements from the base material and impurities coming from other part such as C, O, Fe and so on. In the modified layer, He bubbles in nano-size and fine dislocation loops are densely formed. It is likely that these defects were mainly formed under He-GDC. In case of H-GDC, on the other hand, deposition of C occurred on so called shadow areas where plasma cannot glow well. In actual, a retro-mirror placed on the protection wall lost good reflectivity under the H-GDC performed at the start-up stage of the experimental campaign. Once main plasma discharge experiments have started remarkable sputtering erosion at the surface and radiation damage in the sub-surface region occurred due to bombardment of energetic charge-exchanged neutrals. Deposition of C originated from the divertors made of graphite was also remarkable.

As known well, plasma facing surfaces can be classified into two categories; deposition dominant area and erosion dominant area. In the former, C atoms were deposited with small amount of Fe and Cr, elements of stainless wall. Its surface is colored remarkably depending on the thickness of the deposition. In the latter, thickness of the surface modified layer becomes thicker up to about 20nm in W and about 30nm in stainless steel. Its surface is slightly colored in light brown due to the very dense helium bubbles as shown in the TEM micrograph of the figure. Deposition dominate area widely distributes on the protection wall from which strike-points on the nearby divertor plates can be seen through. It was known that C atoms straightly arriving from the strike-points contribute mainly to the formation of the C rich deposition dominant area. Installation of closed divertors reduced the deposition dominant area, because their larger divertor plates act as good screen for the C atoms from the facing divertor. Installation of closed divertors did not change the fundamental properties of the wall surfaces nearby.

Formation of the He bubbles, which occurs generally in metals and alloys, seriously affects not only on mechanical properties of the surface region but also on retention and desorption of implanted plasma particles. For example, ability in H retention of W exposed to LHD plasma through the experimental campaign is about 30-100 times higher than that of the unexposed W. Most of the H isotope implanted near the room temperature desorb by heating up to 500K. On the other hand, desorption of H isotope from the W exposed in the deposition dominate area, whose surface has turned in brown, continues up to 1200K. Such strong desorption ability for H (strong wall pumping) will be profitable for short pulse discharges but makes it difficult to control particle balance under the long pulse operation, because highly retained H in the wall may act as uncontrollable H source.

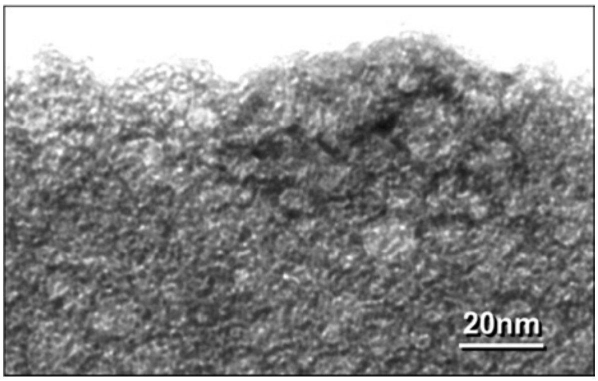

Figure TEM micrograph of W exposed to whole plasmas through Cycle-15 on the protection wall near 9I port.