§38. Microstructural Analysis of Mixed-material Deposition Layer Formed on the First Wall of LHD by Using Nano-geological Diagnosis

Tokitani, M.,
Masuzaki, S., Yoshida, N., Noda, N., Sagara, A., Yamada, H., Muroga, T., LHD Experiment Group

One of the key issues of the establishment for steady state reactor system is impurity control. A steady state plasma operation of the high temperature plasma erodes a significant amount of wall materials on the one hand, and similar amount of deposits are formed on PFCs. In general, thick deposited layer could be unstable and possible source of impurity (dust) for plasma. The deposited layers and the dusts include a huge amount of tritium. Such a mobile products with a radiation isotope is one of critical concerns in the fusion reactor. Then, growth of the deposits and their fragmentation to dusts should be well understood and controlled in future. In order to prevent such a undesired impurity emission, understanding of material characteristics in nanometer level is very important. To clarify the micro structural characterization of deposits, we need cross-sectional observation of the deposition layers in nanometer level. However, such observation has never been done so far in the fusion research field, because it has large technical hurdle. For example, since deposition layer is very thin and brittle, it is difficult to fabricate a cross-sectional sample for nano-observations. In order to solve this problem, we applied focused ion beam (FIB) fabrication technology. After fabricate the sample, cross-sectional nano-geological observation (diagnosis) is performed by using transmission electron microscope (TEM).

Si specimens were mounted on the first wall surface for collection of the deposits as shown in Fig. 1-(a) and -(b), and then, exposed to the 2007FY LHD plasma experiment. Their positions were about 20 cm from the carbon divertor array. After the campaign, specimens were extracted, and were fabricated as the thin film cross-sectional samples by using FIB for TEM observation.

Fig. 2-(a) and -(b) show the cross-sectional TEM images of the deposition layer formed on the Si substrates. Their positions correspond to the (a) and (b) in Fig. 1. The upper side of the figures is the deposition layer and the lower side is the Si substrates. The deposition layers have very fine and stratified structures in nanometer level. From the electron diffraction pattern analysis indicates very fine amorphous like structures. It is considered that the deposition elements were piled up in turn due to the plasma wall interactions. The thickness and microstructure of the deposition layer was different between position Fig. 2-(a) and -(b). The main component of the deposited element in the layer of Fig. 2-(a) and point (3) in Fig. 2-(b) was carbon. While, point (1) and (2) in Fig. 2-(b) are Fe. The reason why depth profile of the deposited element was different even at the one deposition layer is closely related with the scheme of the plasma operation history. During the glow discharge cleanings (GDCs), metallic elements such as Fe were deposited on the first wall surface. The carbon layers were mainly formed during the main plasma discharges. Due to these repetitions, multi layer structures were created. Furthermore, the fine incline stripes can be observed in the carbon deposition layer indicated by arrows in Fig. 2-(a) and -(b). This means that carbon impurities were deposited from the one typical direction as the neutral carbon atoms. While, in the perpendicular TEM view to Fig. 2-(a) and -(b) image (not shown here), these stripes had the simply normal direction (not incline). Thus, incoming direction can be determined parallel to the Fig. 2-(a) and -(b) plane.

In order to understand the microstructure of the deposition layer formed on LHD during 2007FY campaign, cross-sectional nano-geological observation (diagnosis) was performed by using FIB fabrication technique and TEM observations and the following conclusions were obtained. The deposition layer has very fine amorphous like and stratified structures in nanometer level including Fe and C elements. Formation of such a stratified structure must be closely related with the scheme of the plasma operation history. The main components of the incoming C impurities are neutral atoms and their incoming direction can be deduced by using incline stripes created in the deposition layer.

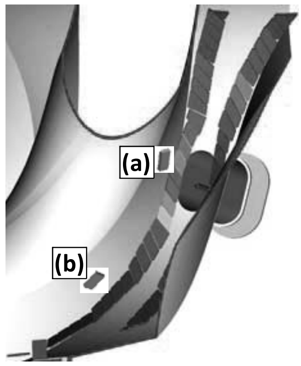

Fig. 1. Specimens position of the (a) and (b) specimens on the first wall surface of the LHD.

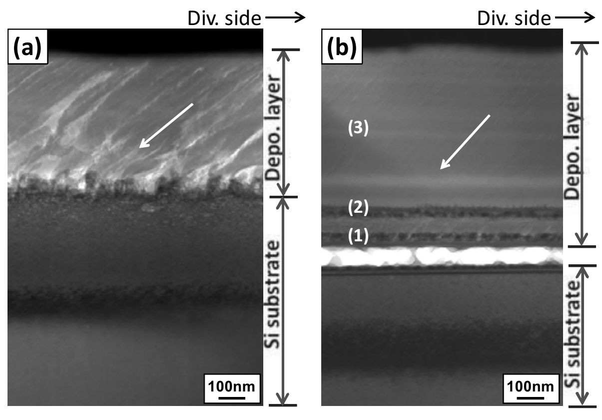

Fig. 2. Cross-sectional TEM image of the deposition layer formed on the (a) and (b) positions in Fig. 1.