§36. Optical Property Change on the First Mirror for Plasma Diagnostics Used in LHD

Tokunaga, K., Fujiwara, T., Yoshida, N. (Res. Inst. Appl. Mech. Kyushu Univ.),
Ohtawa, Y. (Grad. Sch. of Engn. Sci. Kyushu Univ.),
Akiyama, T., Kawahata, K.

Retro-reflectors consisted of three gold-plated flat mirrors made of stainless steel were used in the 4th experimental campaign of LHD for the CO_2 laser polarimeter. This type of reflector has a hollow corner cube structure and is used often for the parallel reflection to the incident beam. Because they were fixed on the first wall, the optical reflectivity was drastically dropped during the experimental campaign due to the plasma-surface interaction. In order to evaluate the optical properties in detail and to understand the mechanisms of the reflectivity reduction, which is essential for development of reduction-free retro-reflector, optical and material properties of the mirrors' surfaces have been examined extensively.

Optical reflectivity of the dented center part, where the three mirrors meet and was used for the reflection, reduced drastically; reflectivity was almost zero for ultraviolet and visible light and about 70% for infrared region. On the other hand, SEM observation showed that the surfaces of the mirrors were covered by thick depositions (about 2μm) with very rough surface. Surface roughness was about 200-400nm due to meso-scale bulges covering the surface entirely. The surface roughness due to the bulges must be one of the major mechanisms for the reflectivity reduction but only for the ultraviolet and visible region.

Cross-sectional structure and its chemical components of the deposits were observed by STEM with EDS microscopically. Figure 1 shows a STEM image of the deposit layer. The deposition has very clear layer structure reflecting plasma discharge conditions; for example, co-depositions of Fe and Cr, element of the first wall with nano-scale dense He bubbles for He glow discharge cleaning phase and codepositions of Fe, Cr and O for high temperature hydrogen plasma discharge phase. The deposition layer formed latter phase contains rather large FeO crystals of about 20nm but no bubbles as shown in ① in Fig.1. This fact means that the ratio of O flux to that of metallic impurities under high temperature plasma discharges is much higher than that under the He glow discharge cleaning. Optical reflectivity of FeO crystal is almost zero in very wide range of wave length. In addition, fine He bubbles also reduce reflectivity even at infrared region. Formation of the Fe-oxide layer and helium bubbles are other mechanisms of reflectivity reduction of the LHD retro-reflectors. It was also found that leakage of water leaded to the formation of the mesoscale bulges as shown in interface between ① and ② in Fig.1.

It should be emphasized that cross-sectional observation of the deposition in nano-scale is very powerful for deep understanding of actual plasma-surface interaction in each device. Based on these results a new retro-reflector which can evade plasma surface interaction even on the first wall has been designed and the test of its performance is now going on in LHD.

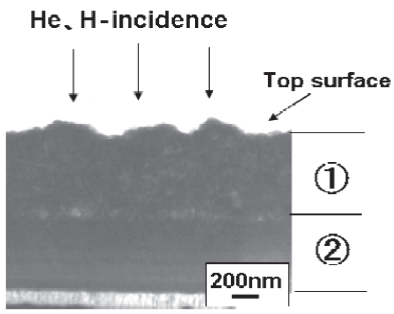

Fig. 1 STEM image of deposited layer