§26. R&D of Retro-Reflector for LHD with Anti-Reflection Reduction Mechanism

Yoshida, N., Tokunaga, T., Fujiwara, T. (Kyushu Univ.),
Akiyama, T., Tokitani, M., Kawahata, K.

Plasma facing surfaces of in-vessel components suffer various kinds of PSI such as bombardment of plasma particles, re-deposition of impurity atoms and heat load. Actual phenomena happened in the plasma confinement devices are synergistic effect of the fundamental processes. This holds good in the plasma facing mirrors for plasma diagnostics.

It was reported that retro-reflectors placed in LHD were suffered extraordinary PSI due to its unique hollow structure and their optical reflectivity reduced drastically in result[1]. Development of advanced retro-reflectors working under strong PSI is an urgent issue not only for LHD but also for ITER. In the present work, therefore, two types of protection structures for long-life retro-reflectors, (a) protection with bended tube and (b) direct cover with window materials, were examined by placing test model on the protection wall of LHD in Cycle 13 (2009).

Test model for (a) is shown in Fig.1. Bend angle of the protection pipe is 45º and its length was designed as long as possible, about 5 times longer than its diameter in the present case, to reduce influx of plasma particles and impurities. After the end of the plasma exposure through Cycle 13, optical properties and microstructure of the reflectors were examined.

It was successfully demonstrated that the protection tube with an obtuse angle could sufficiently reduce PSI on the reflectors. As shown in Fig.2 reflectivity of the first mirror (Au) and the second mirror (Au) did not decrease significantly. TEM observation of the pre-thinned specimen placed on the flat mirror indicated that the deposition of impurities were negligibly small. Nano-scale dislocation loops were formed slightly in the first mirror facing to the plasma but no damage in the second mirror. These results indicate that influx of impurities and high energy particles which can transfer impurities to the retro-reflector is very low and therefore the surface properties of the mirrors placed in the protection tube did not changed even after one experimental cycle.

It is worth to note that rather thick deposition was formed on the inner wall near the open edge of the protection tube. The deposition distributed on one side of inner wall and impurities did not reach beyond about 5cm (about 2.5 times of the diameter of the protection tube). The inner surface of the opposite side is very clean due to sputtering erosion. These results indicate that large amount of impurities are formed at the opening mouth of the protection tube due to the sputtering erosion under glow discharge cleaning, however sputtered impurities could not reach beyond 5cm. It was corroborated that protection of a long tube with an obtuse angle is very effective to suppress the reduction of reflectivity of retro-reflectors.

In case of (b), typical window materials such as synthetic quartz (SQ), crystalline quartz (CQ), ZnSe and high resistive silicon (Si) were exposed to plasmas. After taking out from LHD, changes of optical transmittency for several kinds of laser were measured. By picking up cross-sectional micro-samples from the bombarded surface, change of microstructure was observed by TEM. The transmittency of Si and ZnSe decreased slightly. As shown in Fig.3, quite thick impurity deposition layers were found on the surface of SQ and CQ while not much on ZnSe and Si. Since the formers are insulator, it is expected that glow discharges could not sputter the deposited impurities. These results indicate that covering the retro-reflector by high resistance Si for laser in FIR and by ZnSe for visible-IR is a simple method to keep long the retro-reflectors at reasonable condition.

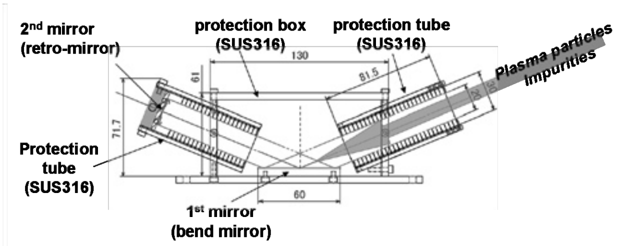

Fig. 1. Test model of bend type retro-reflector examined in the present work

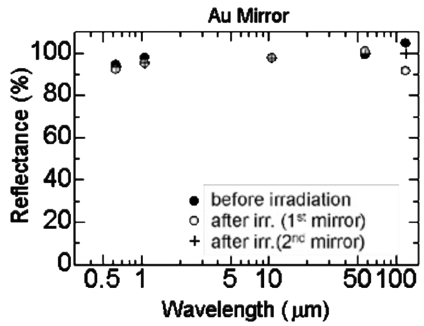

Fig. 2. Change of optical reflectivity of the 1st and 2nd mirrors

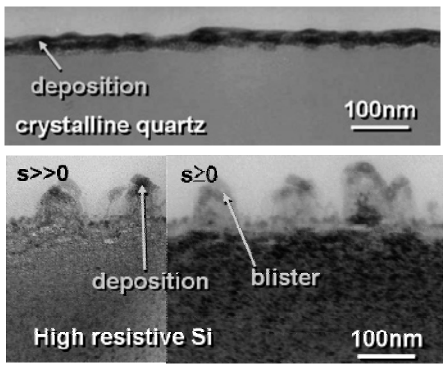

Fig. 3. Cross sectional TEM micrographs of crystalline quartz (CQ) and high resistive silicon (Si).

1) T. Akiyama et al., Rev. Sci. Inst. 78, 103501(2007)