§18. Change of Optical Properties of Retro-reflector Installed in LHD

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Because of limitations of port access, diagnostic mirrors often have to be installed inside a vacuum vessel. These days, degradations of optical properties due to interactions between plasmas and mirror surfaces are becoming a serious problem. Since inner mirrors in ITER cannot be replaced frequently, it is indispensable to understand how much the reflectivity deteriorates, the mechanism and the dependence of the degradation on the wavelength and mirror materials.

Figure 1 is a photograph of test mirrors installed in LHD. These mirrors are exposed to plasmas during whole 10th experimental campaign. It consists from flat mirrors with different metal (Mo, stainless steel, Cu, CrZrCu) and mirrors with protection cylinders (flat and roof mirrors). Mo mirror with the protection cylinder is to study effects of the cylinder. Roof mirrors are to study how sputtered particles are transported on the mirror surface because it was reported that the deposited particles were accumulated to the central region of a retroreflector [1, 2]. These mirrors are installed on helically winded coils near 8.5UL ports.

Figure 2 shows the reflectivity of four flat mirrors before and after exposure to plasmas in the wavelength range from visible to far infrared. The reflectivity for longer wavelength than 10 μm does not deteriorate very much regardless of the materials. However, the reflectivities of Cu and CrZrCu mirrors in near infrared and visible region decrease significantly while these of Mo and stainless steel mirrors show just a slight decrease. In order to understand how the reflectivity decrease, the surfaces were observed with SEM and materials on the mirror surfaces were analyzed with EDS. Photograph of the surface of CrZrCu mirror after the exposure is shown in Fig.3. Spherical objects, whose diameters are less than 1 μm, are found on the surface. EDS analyses show that these objects consist from cupper not iron or carbon which come from the vacuum vessel wall and divertor plates. Since cupper is rarely used in LHD except this mirror, these objects are expected to be formed by gathering sputtered cupper. Similar objects are observed on the Cu mirror surface, too. The decreases in the reflectivity of CrZrCu and Cu mirrors seem to attribute to surface roughness due to these spherical objects and depressions. On the other hand, surfaces of stainless steel and Mo mirrors are still smooth even after the exposure to plasmas. This is due to low sputtering yields.

There were impurity depositions, which causes significant degradation in the reflectivity as shown in Fig. 2, on the Mo mirror with the protective cylinder while no deposition on the flat Mo mirror without the cylinder. These depositions are expected to come from the vacuum vessel or the cylinder. Though the cylinder is effective to reduce direct bombardment by charge exchange particles, it also plays a role as a source of deposition particles. Hence the studies of shapes of the cylinder to prohibit impurities from falling on the mirror surface are going now.

[1] T. Akiyama, *et. al.*, Rev. Sci. Instrum. **78**, 103501 (2007).
[2] N. Yoshida et. al., 23rd annual meeting of The Japan Society of Plasma and Nuclear Fusion Research, Tsukuba, 30aB05 (2006).

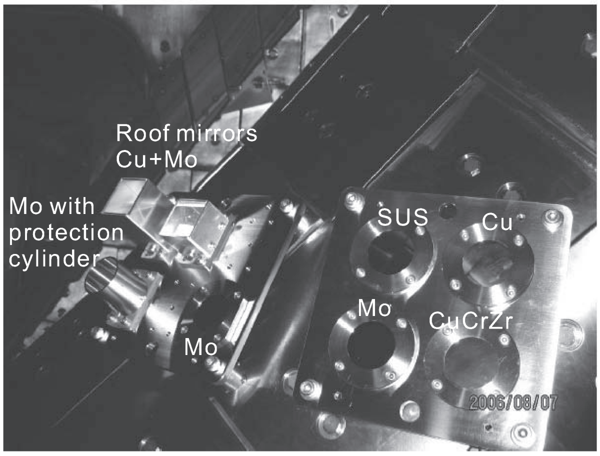

Fig.1: A photograph of test mirrors installed in LHD vacuum vessel.

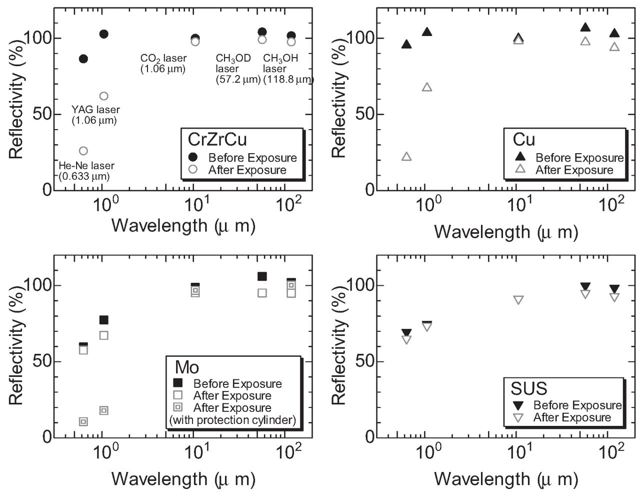

Fig.2: Reflectivity of flat mirrors (CrZrCu, Cu, Mo and stainless steel) before and after exposure to LHD plasma

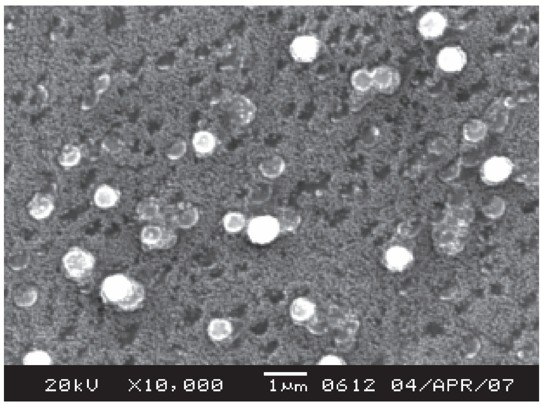

Fig.3: Surface of CrZrCu mirror after exposure to LHD plasma