§26. Reflectivity Degradation of In-vessel Mirrors by Helium Bubbles

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Laser diagnostics and spectroscopy often need to install mirrors in a vacuum vessel. One of problems of in-vessel mirror is reduction of the reflectivity. So far, impurity deposition on the mirror surface and erosion by plasma and charge exchanged particles are well known as reasons of the degradation. In addition to those, helium bubbles that are formed by fusion-produced helium will also cause the reflectivity degradation in future fusion reactors. Past researches found complicated dependences of the helium bubble formation on energy and flux of the incident helium atoms, materials and temperature. In this study, we investigated the reflectivity degradation of mirrors for visible ~ infrared region by the helium bubbles under expected reactor conditions.

The in-vessel mirrors on ITER will be exposed to flux of fusion produced helium. Since the energy and flux of helium and its distribution over the first wall have been evaluated these days, we will conduct helium exposure experiment under those conditions. First, we searched the parameter range of helium at expected positions of mirrors.

He flux and energy

Table 1 is the flux and energy of He ion and He neutral at mirror locations [1]. One of author is designing a laser interferometer on ITER [2] and the first mirrors and a corner cube mirrors will be installed outboard and inboard side on the equatorial plane. It is expected that He atom flux is the maximum, 1×10^{18} $m^{-2}s^{-1}$, at the inboard side.

Mirror temperature

Since the mobility of helium atoms strongly depends on the material temperature, formation of helium bubbles also depends on the material temperature. Mirrors in the outboard side will be cooled with water whose temperature is 70 deg. On the other hand, corner cube mirrors (CCM) which will be installed on the inboard side will not be able to be cooled and the temperature will rise up to 450 deg.

Mirror material

It is expected that helium bubble formation also depends on the mirror material. In the viewpoints of the reflectivity and sputtering yield, the tungsten and rhodium are candidate for the mirror material. They are determined from the erosion which are evaluated from the energy and flux of He during main discharges. Supposing that the discharge duration is 400 s, an erosion thickness will be 10 µm for 2,200 and 4,500 discharges, respectively. Especially, the rhodium has higher reflectivity at visible and near infrared region, it is suitable for laser diagnostics which use infrared laser light for probing and visible laser light for alignment. However,

		Outboard	Inboard
Flux (m^{-2} s^{-1})	He atom	6×10^{17}	1×10^{18}
	He^{+}	3×10^{17}	1×10^{17}
	He^{++}	3×10^{17}	9×10^{17}
He energy (eV)		50	2

Fig. 1: Characteristic of He atoms/ions at the first wall in ITER

rhodium is precious metal, coating on cupper is common use. Characteristics of coating will be different from bulk material because there will be more defections where helium will crump and the surface layer will exfoliate due to microcrystalliate.

Based on the above research, we will conduct the exposure experiments to helium plasmas under conditions which satisfy bellow conditions.

- He energy of 50 eV
- Irradiation up to a fluence of 2×10^{24} m^{-2}, which corresponds to ITER 5,000 discharges (400 s each)
- Mirror temperature lower than 450 deg.
- Mirror material is rhodium

Now we are preparing the rhodium mirrors. The coating will be made with a magnetron sputtering device at Nagoya University. The mirrors coated with rhodium are irradiated by helium plasmas in the linear plasma device “NAGDIS-II” at Nagoya University in 2016.

1) A.S. Kukushkin, 14.04.08, ITER_D_27TKC6
2) T. Akiyama et. al., submitted to Rev. Sci. Instrum.