§23. The Development and Installation of Titanium Evaporation Devices for the Wall Conditioning in the LHD Vacuum Vessel

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In the startup phase of the plasma experiment in the LHD, oxygen is the most crucial impurity because of the large radiation amount. To supress the oxygen effect, titanium (Ti) evaporation device was developed (see Fig.1(a)). Evaporated Ti atoms form the Ti film which has getter effect. This film is expected to have two effects; covering of oxygen and oxide layer on the vacuum vessel surface, and getter effect. For covering oxide layer by Ti film, the necessary thickness of the film is 3 monolayers [1]. In the LHD, three Ti evaporation devices are installed. One hour operation of them provides the Ti film whose thickness is over 3 monolayers (~0.9 nm) on ~30% area of the LHD plasma facing surface.

Figure 1(b) and (c) show the Ti source of this device which consists of 4 small Ti balls (Ti sublimation pump head; ANELVA,Inc.). These Ti balls are connected in series on the boron-nitride disk (ϕ114 mm). The heating power is about 1.5 kW (50 A, 30 V). The characteristics of this Ti source, such as, the angular distribution of Ti film thickness, life time, were examined in a test chamber (f320 × 383 mm). 17 sample-plates (10 × 20 mm) were set on the wall facing Ti source to obtain the angular distribution of Ti film thickness. The distance between Ti source and sample-plates are about 160 mm. The film thickness was measured by the surface roughness probe which uses the pick up needle. Figure 2 shows the angular distribution of Ti film thickness. In the region above the Ti source, the film thicknesses on the sample-plates are 1-1.2 mm per 1 hour operation. Using this result, the Ti film thickness (T) can be predicted by the expression of;

$$T_{(nm)} = 4300 \times t_{(min)} / r^2_{(cm)},$$

where r is the distance from the Ti source, t is the operation time. During this examination, separations of the Ti films were observed. Such separated Ti film becomes the source of dust in vacuum vessel, and it must be minimized. The critical thickness is about 10 μm in this examination. In the LHD vacuum vessel, the distance between Ti source and the nearest wall is about 30 cm. Thus, total 30 hours is enough operation time to make the separation of Ti film. Therefore, the total operation time should be limited to be 30 hours. In the examination, after 30 hours operation, the amount of evaporated Ti atoms were not decreased, that is, the life time of this Ti source is enough to operate in LHD up to the limit time.

In the LHD, three Ti evaporation devices are installed from 2.5-L, 5.5-L, 9.5-L port, respectively. Usually, the Ti sources are in the divertor region during operation, and drawn into the port during plasma experiment to avoid the striking of the divertor plasma. This movement is driven by the non-magnetized air cylinder (rod diameter: 30 mm, cylinder inner diameter: 80 mm), and the moving length is 50 cm. For estimate the Ti film thickness insitu, the measurement of Ti film's electrical resistance will be done. Small plates (10 × 30 mm) made of electrical insulator (BN) are set near the Ti sources, respectively. The calibration was done in the SUT device. Figure 3 shows the electrical resistance of the Ti film. As the growth of the film thickness, the dependence of the film's electrical resistance on the film thickness is close to that of the Ti bulk. For the difficulty of cleaning the BN plate surface insitu, this method is available only in early operation phase, but useful data concerning to the estimation of Ti film thickness can be obtained.

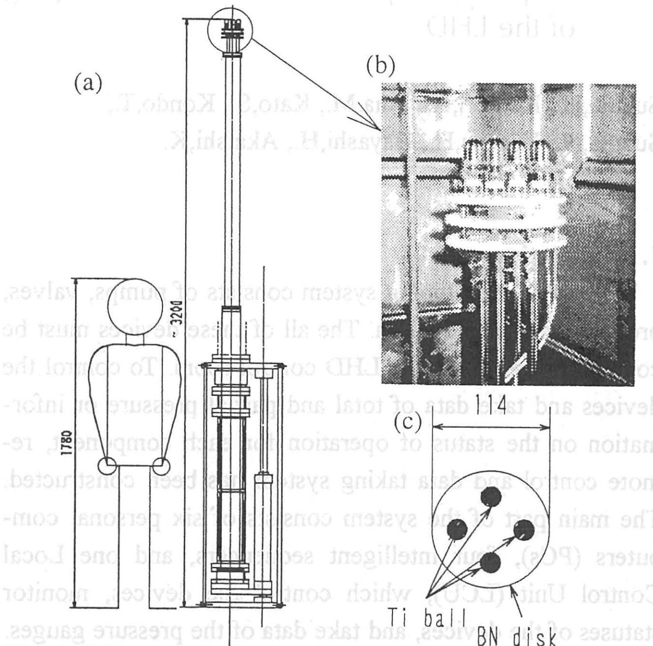

Fig. 1. Schematical view of the Ti evaporation device. (a) Whole structure, (b) Ti source in the LHD port, (c) top view of the Ti source

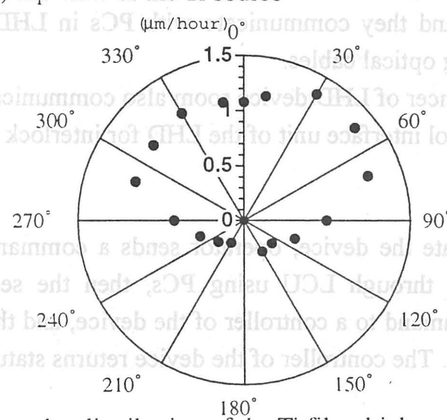

Fig. 2. Angular distribution of the Ti film thickness per hour on the sample-plates. Ti source locates on the center of this circle. The sample-plates are 160mm away from the Ti souce.

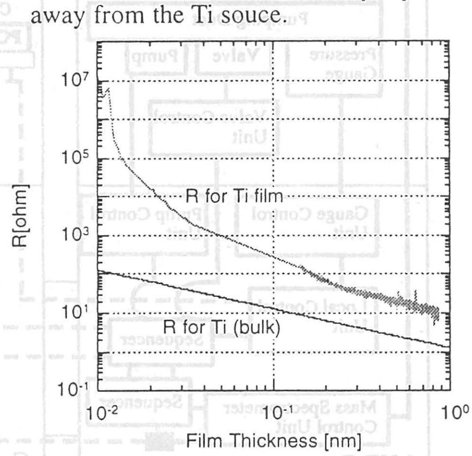

Fig. 3. The measurement of the electrical resistance of the Ti film for thickness monitor

Reference
[1] A. Sagara et al., J. Nucl. Mater. 93&94, 333(1980)