Investigation of effective cleaning method using ion cyclotron conditioning in LHD

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The ion cyclotron conditioning (ICC) is one of the conditioning methods to reduce impurities and to remove tritium from the plasma facing components. Advantages of ICC are to be operated under strong magnetic field for fully torus area and can be operated with high pumping efficiency. In particular, ICC in helical devices can be operated using the same magnetic configuration for of main plasma and a shot by shot operation is easy. The advantages of ICC in LHD are the durability of long-term operation and the flexibility of input power with pulse phases. Using material probe system, effective cleaning area by ICRF conditioning is estimated. On the plasma facing area of material holder, a lot of helium babble is observed by transmission electron microscope (TEM), but the gap area have no damage. It is suggested effective particles come to the wall straight and a clearing for shadow area is difficult.

Keywords: LHD, Wall conditioning, RF plasma, PWI, T inventory

1. Inroduction

The ion cyclotron conditioning (ICC) is one of the conditioning methods to remove tritium from the wall [1,2]. The operation of experimental devices for fusion plasma with superconducting coils needs long time duration for increasing and decreasing the magnetic fields. As typical wall conditioning methods, a DC-glow discharge cleaning is operated such as JT-60U and LHD [3,4] during non-magnetic field. In future, the superconducting reactors, which still will be operated over long discharge duration and will deuterium/tritium mixtures. Therefore, for future devices, a wall conditioning method in magnetic field will be required in general.

As a general wall conditioning method to remove impurities and retention gases, two type scenarios are planed in the international thermonuclear experimental reactor (ITER), one is an initial conditioning before main experimental campaigns and second one is a day by day conditioning during campaign. During experimental campaign, a magnetic field will be kept in ITER, and then the ICC method during magnetic field is important. As other reason, tritium retention is one of serious problem in ITER and the ICC is considered as a tritium removal method from the first wall and divertor target.

In the large helical device (LHD) [5], is provided with a superconducting coil as confinement magnetic field and DC-glow discharge cleaning are used in most case to operation the wall conditioning [4]. As other wall conditioning method, boronization and titanium gettering are operated a few times during experimental campaign.

Ion cyclotron range of frequency (ICRF) heating devices is developed for a high power and long pulse discharge plasma heating in LHD [6,7]. Using same ICRF antenna sets, ICC was operated in 2005 and a successful operation was done as an initial operation [8].

From experiences in LHD and AUG, effective cleaning areas by ICC are considered smaller than by glow discharge. But this RF plasma wall interaction is not investigated yet. In this paper, effective cleaning area by ICRF conditioning was estimated using damages on material probes for different area.

2. Experimental setup

For the ICC operation, one of the ion cyclotron ranges of frequency was choosing and this frequency is

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the second harmonic heating for helium. This is a heating method which takes advantage of finite Larmor radius effect and a heating efficiency at f = 38.47 MHz is about 40%. As a confined magnetic field, a magnetic field, B_t,=2.75T, and a magnetic axis, R_{ax}=3.6m were used. Hydrogen and helium partial pressure were measured by quadruple mass spectrometry (QMS) with a sampling time of 1 sec. As plasma facing components the first wall consists of stainless steel 304 and a divertor is made of carbon. A RF input phase of 3 sec and interval phase of 2 sec are used and it is determined by a stored duration time of data acquisition system. An input power and a helium pressure were scanning, but stable discharge was kept during ICC operation.

3. Material probe experiment in ICC

During ICC in FY2006, stainless steel samples on hexahedron block holder is installed using the movable sample stage system at 4.5L port and this stage level was set at just first wall as shown in Fig.1.

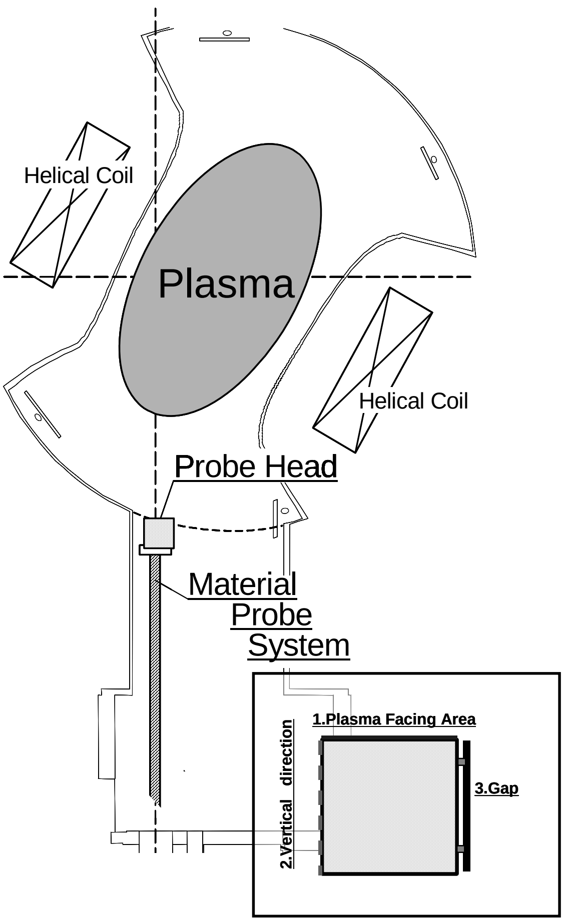

Fig.1 material probe system and sample holder.

Sample holder has three kinds of facing on this block as following 1) plasma facing area, 2) Vertical direction for plasma facing area and 3) Gap area. Samples installed on holder directory on plasma facing and vertical direction, and vertical area facing in-vessel component. The gap area is demonstrated between tiles and thin plate is connected to base holder with slit of 1.5mm. Samples installed on holder, and then samples are not exposed to plasma directory.

This sample holder kept during ICC plasma and integrated exposure time is about 4000 s. Stainless steel samples is analyzed by transmission electron microscope (TEM) and these bright field images are shown in Figs.2. From comparison number of damages due to helium babbles on different position, only plasma facing area as shown in Fig.2(a) has large number of damages. For a sample on the gap at position 3 in Fig.1, damage is not observed by TEM analysis. From helium babbles are

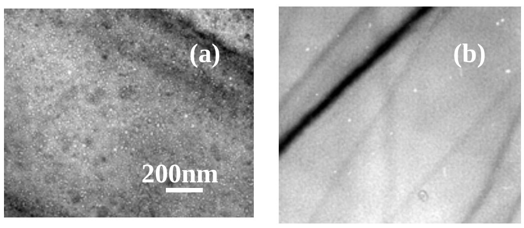

Fig.2 Bright field images by TEM, (a) on plasma facing are and (b) vertical area.

produced by an interaction between RF helium plasma and target samples, large number of damages are estimated as strong interaction in this experiment. These results are suggested effective CX particles come to the wall straightly and a cleaning for shadow area will be difficult.

4. Particle flux from RF conditioning plasma

Using Natural Diamond Detector (NDD) [11] Charge exchange neutral particle is measured as shown in Fig.3. This NDD is installed at 4.5 lower side near the port and CX neutral particles by ICRF plasma can be detected on this poloidal cross-section. Using NDD data at shot # 70540, particle flux is estimated. Detected particle thought out of slit of 2mm and this integrated time is about 1.8 s. At shot #70840, using detected counts of full energy spectrum by NDD as shown in Fig.3 and area of detector, particle flux of charge exchange neutral is calculated about $1.6 \times 10^5 \sim 3.2 \times 10^5$ [$s^{-1}cm^{-2}$]. At this experiment, a particle flux can measured only RF input of frequency of 38.47 MHz, and it is to need changing an integrating time of time frequency for other frequency and low power case.

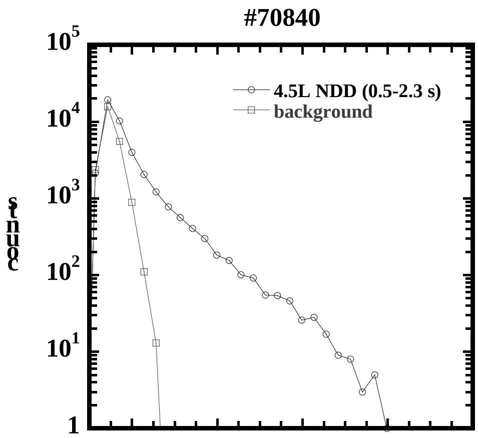

Fig.3 Energy spectrum of Natural Diamond Detector

5. Summary

Using material probe system, effective cleaning area by ICRF conditioning is estimated. From three kinds of area, number of helium bubble on samples is different. On the plasma facing area of material holder, a lot of helium babble is observed by transmission electron microscope (TEM), but the gap area have no damage. These results are suggested effective particles come to the wall straight and a clearing for shadow area is difficult. During ICC, particle flux is measured about $1.6 \times 10^5 \sim 3.2 \times 10^5$ [$s^{-1}cm^{-2}$] at port area.

In future works, using this estimated cleaning area comparison of removal efficiency of tritium by different method is important.

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