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Carbon Impurity Seeding to Deuterium Plasma Using a Deuterated Benzene C_6D_6.

重水素化ベンゼンC_6D_6を用いた重水素プラズマ中への炭素不純物供給実験

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Control of tritium retention and its removal from the first wall of future fusion devices are the crucial issues for safety and effective use of the fuel. We have investigated the scavenger effects of N_2 added into D_2/CH_4 plasmas using a small helical device, Heliotron-DR. Hydrogen and deuterium is mixed with the introduction of the CH_4 containing hydrogen to deuterium plasma. So, we were subjected introduction of C_6D_6 as the carbon impurity that does not contain hydrogen. Carbon film deposition is also possible with carbon impurity introduction by C_6D_6.

1. Introduction

The wall material of a nuclear fusion reactor is tungsten, beryllium, and carbon. Tungsten is used in ITER [1, 2]. Tungsten has the advantage of high melting point, low sputtering rate, and low tritium storage. But, tungsten has the disadvantage of weak to thermal shock and radiation loss. On the other hand, Carbon material is advantage of strong to thermal shock. But carbon material has the disadvantage of high tritium storage. So, we thought carbon material is used in fusion reactor by reduction of tritium storage.

N_2 introduction into D_2/CH_4 plasmas has been examined as effective methods for suppression of hydrogenated carbon films deposition growth [3,4]. Carbon film deposition is remarkably suppressed adding small amount of N_2 to D_2/CH_4 plasma [5]. Volatile HCN and CN generated in wall surface and gas phase in $D_2/CH_4/N_2$ plasma [6,7]. Furthermore, it was confirmed that the carbon film deposition is suppressed greatly by raising the wall temperature. So, we see that the wall surface reaction greatly affects suppression of hydrogenated carbon films deposition growth.

We've been using CH_4 as a carbon impurity in order to deposit carbon film. But if we use CH_4 as a carbon impurity, it becomes the environment in which deuterium (m/z = 2) and hydrogen (m/z = 1) are mixed. As a result, identification of particles is difficult. We want to simplify the identification of particles in order to investigate the cause of the carbon film deposition suppression by N_2. Therefore, it is necessary to realize hydrogen-free environment. We decided to use the C_6D_6 instead of CH_4 as a carbon impurity.

In this paper, we introduced C_6D_6 as a carbon impurity to achieve hydrogen-free environment using a small helical device Heliotron-DR, which can generate low density and temperature, and pure D_2 plasmas in steady state condition. Carbon film deposition is also possible with carbon impurity introduction by C_6D_6.

2. Experimental setup

Figure 1 shows C_6D_6 introduction system. Liquid of C_6D_6 in test tube is evaluated by exposing to vacuum. Liquid of C_6D_6 changes steam of C_6D_6 which is gas condition. We control the introduction amount of C_6D_6 using mass flow controllers of CH_4. Introduction amount of C_6D_6 is calculated by reading the scale of the test tube. Low temperature and steady state rf plasmas with D-C-N reactive species were generated in Heliotron-DR device [1] with small amount of steam C_6D_6 or CH_4, and N_2 introduction into D_2 plasmas. Rf power of about P_{rf} ~3.0 kW was launched into plasma using three rf antennas. The experimental gas pressure was 0.5-0.8 Pa. The purpose of the experiment is investigation which the suppression effect of carbon film formation and the influence of the tritium retention in the carbon film by N_2 introduction and the reaction of the carbon related molecules and dust. Quadruple mass spectrometer (QMS) and optical emission spectroscopy (OES) were used to observe the reactive species generated in D-C-N reactive plasmas. Quartz crystal microbalance (QCM) was used to measure of carbon film thickness during the experiment. The steady state magnetic was generated by toroidal and helical coils. The electron temperature and electron density measured by a triple Langmuir probe were 5-15 eV and $(0.5\text{-}2.4)\times 10^{16}$ m^{-3}, respectively. The chamber wall was heated up by a ribbon heater system would around the outer vacuum vessel. The average temperature of chamber rose to ~320-345 K, when ribbon heater system operated.

3. Experimental results and discussion

Figure 2 shows introduction amount of C_6D_6 in the display value of the mass flow controller of CH_4. Introduction amount of C_6D_6 is increased linearly with the display value of the mass flow controller of CH_4. So, we were successful control of introduction amount of C_6D_6 by using the mass flow controller of CH_4. In addition, mass spectra of hydrogenated particles, for example CD_3H and CD_2H, are observed weakly from D_2/C_6D_6 plasma. So, we were able to realize a hydrogen-free environment.

Figure 3 shows mass spectra of D_2/C_6D_6 plasma and D_2/CH_4 plasma. Mass spectra of CD_a, C_2D_b, C_3D_c C_4D_d, and C_5D_e are observed in D_2/C_6D_6 plasma. Mass spectra of CD_a, C_2D_b, C_3D_c C_4D_d, and C_5D_e are generated by dissociating C_6D_6. So, C_6D_6 sufficiently dissociated in D_2 plasma. Mass spectra of CD_a and C_2D_b are significantly observed in D_2/C_6D_6 plasma and D_2/CH_4 plasma. So, C_6D_6 is able to use as a carbon impurity, and it can be expected that generation of the film similar to when using CH_4. Actually, deposited film thickness in D_2/C_6H_6 plasma (C_6D_6:1.19 mg/min) for 4 hours is about 80 nm, but deposited film in D_2/C_6H_6 plasma has not yet been analyzed yet.

We were successful introduction of C_6D_6 as a carbon impurity. We plan to evaluate the deuterium storage amount in this experimental system.

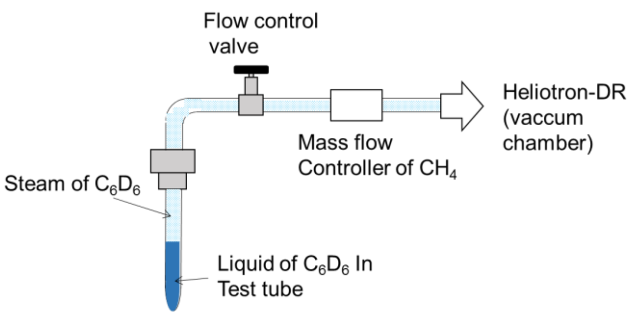

Fig.1 C_6D_6 introduction system.

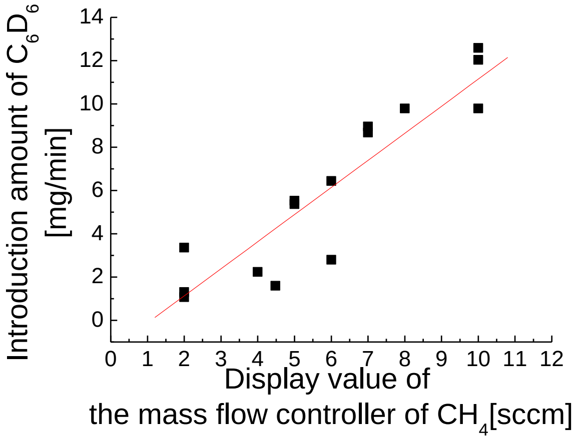

Fig.2 Introduction amount of C_6D_6 in the display value of the mass flow controller of CH_4.

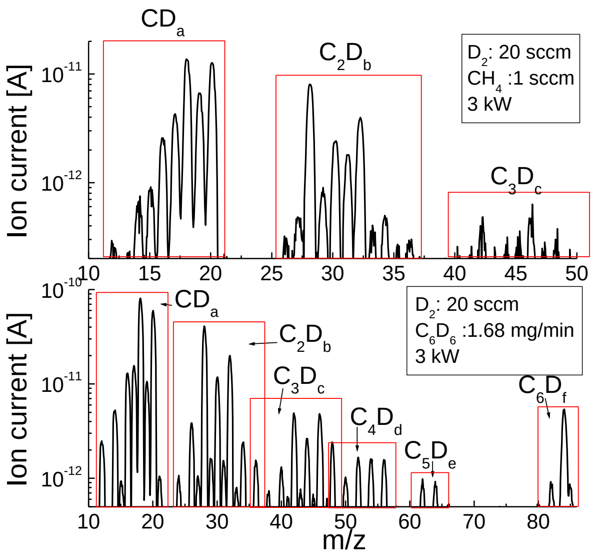

Fig.3 Mass spectra of D_2/C_6D_6 plasma and D_2/CH_4 plasma.

4.References

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