§9. Suppression of Carbon Dust Growth and Hydrogen Retension in Multi-species Low Temperature Plasmas with Nitrogen

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Carbon materials are used for plasma facing components (PFCs) in fusion devices. Carbon Fiber Composite (CFC) is used as PFCs in ITER. The problem is that CFC contains large amount of hydrogen with its sputtering and redeposition. Since tritum that is used as fuel gas in fusion reactors is radioisotope of hydrogen, deposition of the materials containing tritium is a serious issue in fusion reactors. The purpose of this study is to solve the problem of tritium inventory. The control of tritium inventory and suppression of dust particle release is important issues in future fusion reactors[1].

In this paper, we have investigated the effects of nitrogen injection into H_2/CH_4 plasma in the experiments using Heliotron-DR, which generates low density and temperature, and pure H_2 plasma in steady state condition. These conditions are near to remote plasma rather than ICPs's one[2]. Low temperature RF plasmas with H-C-N reactive species are generated in hydrogen plasmas with small amount of CH_4 and N_2 injection. The working gas pressure is ~1Pa. The electron temperature is 5-10eV. The electron density is (0.4-1.6) $\times 10^{16} m^{-3}$ at the plasma edge. From optical emission spectroscopy, volatile CN band spectra were observed in $H_2/CH_4/N_2$ mixture plasmas. From mass spectrometry of $H_2/CH_4/N_2$ mixture plasmas, volatile CN and HCN spectra were observed, which are key particles for suppression of the carbon film and dust formation. In the first experiment using Heliotron-DR, the thickness of carbon film increases by nitrogen injection in relatively low surface temperature Ts~320 K. If the surface temperature is higher than ~360 K, the thickness of carbon film drastically decreases by nitrogen injection as shown in Fig. 1. The parameter dependence of this critical temperature is now under studied experimentally. Results of thermo-equilibrium particle composition show that atomic nitrogen in H-C-N plasma system hinders C-C bond necessary for nucleation in the carbon agglomeration process. In addition, generation of volatile molecules like HCN, NH is expected to contribute the removal of hydrogen isotope from the carbon deposit layer. Following is the results of the experiments using Heliotron-DR. The surface temperature of silicon in the irradiation is Ts=320-370K. Figure 2 shows optical emission spectra of H_2/CH_4 and $H_2/CH_4/N_2$ plasmas. The molecular band spectra of volatile CN and NH radicals are clearly observed in $H_2/CH_4/N_2$ mixture plasmas. Figures 3 shows mass spectra of H_2/CH_4 and $H_2/CH_4/N_2$ mixture plasmas. In $H_2/CH_4/N_2$ plasmas, mass spectra of volatile nitrogen particles like CN, HCN and NH increase strongly compared to those without nitrogen. From these experimental measurements, it can be concluded nitrogen has a crucial role for suppression of carbon aggolomeration and a-C:H film formation in the low temperature plasmas.

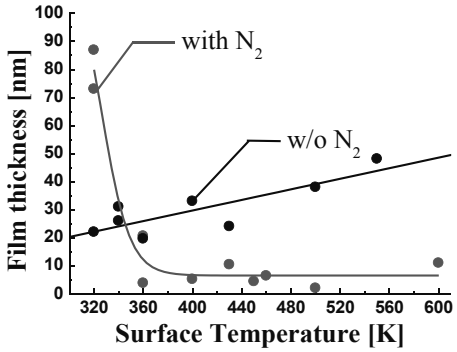


Fig. 1 Temeprature dependence of the deposited carbon film thickness with and without nitrogen injection.

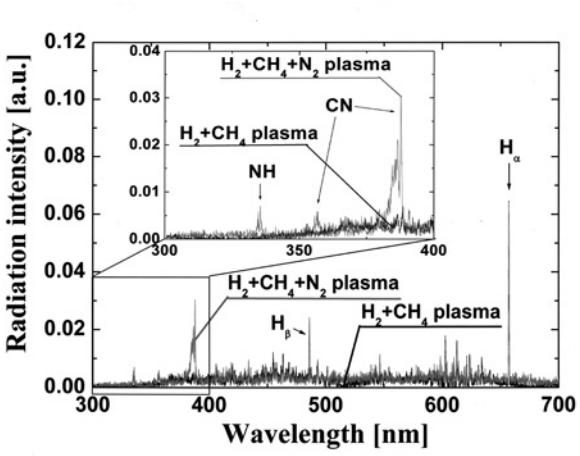
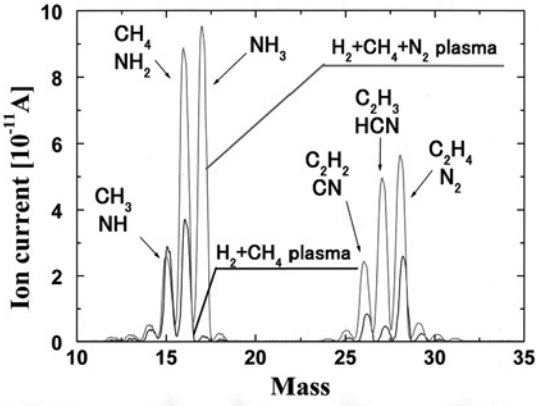


Fig. 2 Emission spectra from the palsmas with and without N_2.



Fig, 3 Mass spectra of the plasmas with and without N_2.

1) F. L. Tabares et al., Phys. Rev. Lett., 105, 175006(2010).
2) M. Kyo et al., Plasma Fusion Res. 5, 004(2010).