# §5. Suppression of Carbon Dust Growth and Hydrogen Isotope Retension in the Low Temperature Reactive Plasmas with Nitrogen

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Carbon Fiber Composite (CFC) will be used as PFCs in ITER hydrogen plasma phase because of their superior thermo-mechanical properties. In the fusion devices using carbon PFCs, carbon materials not only are eroded significantly by hydrogen plasma irradiation but also generate many carbon dust particles with size of submicron to several tens micron. The hydrocarbon particles generated by chemical sputtering of carbon PFCs containing tritium are transported into SOL plasmas and form tritium-containing co-deposits in the cold remote area away from the main interaction area in the divertor plasmas. The control of tritium inventory and suppression of dust particle release is one of key issues for future utilization of carbon materials in the fusion reactor. Nitrogen injection into hydrogen plasmas has been examined as one of the effective methods for suppression of carbon dust growth and reduction of tritium inventory. In the experiments which are performed with $Ar/H_2/N_2$ plasma irradiation to graphite targets, using high-power inductively coupled plasmas (ICPs), we got the results that just a few percent of nitrogen addition ($N_2/H_2$~2%) into $Ar/H_2$ plasmas leads to significant suppression of agglomeration of carbon particles to form large size carbon dust particles in the number of carbon dust particles[1). In this experiment it is considered that volatile C-N bond formation plays an important role to restrain cohesion of carbon particles. When compared with other species present in the cold plasmas, HCN shows very high stability (C-N bonding energy is 8.15 eV while N-H is 3.6 eV). In the experiments using ammonia as a carbon-radical scavenger, the deposition rate was suppressed by ammonia injection. It is considered that HCN formation plays an important role to bring suppression effect[2). In this paper, we have investigated effects of nitrogen addition into $H_2/CH_4$ mixture plasmas on the formation of carbon film and particles using a small helical device Heliotron-DR, which can generates low density and low temperature, and pure $H_2$ plasmas in steady state condition.

When nitrogen gas was added into $H_2/CH_4$ plasmas, mass spectra measured at the pumping manifold show drastic increases of volatile nitrogen particles like CN, HCN and $NH_3$ compared to those without nitrogen. Since the chemical bonding energy of C≡N bond is the highest among the carbonized particles in the C-H-N system (C-H:435 kJ/mol, C≡C:838 kJ/mol, C≡N:887 kJ/mol), it is speculated that the volatile molecules which consist of CN bond (-C≡N) such as HCN and $C_2N_2$, are preferably formed in the cold plasma near the wall surface. Formation of these stable molecules like HCN, $C_2N_2$ can interfere with carbon agglomeration and film formation on the wall. In addition it should be noted that the formation of volatile HCN and $NH_3$ molecules also has a possibility of suppression of hydrogen retention in the wall. Figs. 1(a) and (b) show the film thickness and diameter of dust particles as a function of Ts, respectively. After $H_2/CH_4$ plasmas irradiation, the thickness of carbon film gently increases with Ts. On the other hand, the film thickness of the targets exposed by $H_2/CH_4/N_2$ plasmas strongly depends on the surface temperature. Although the thickness of carbon film increased by nitrogen injection in relatively low surface temperature (Ts~320 K), it is drastically decreased by nitrogen addition when the surface temperature was higher than ~400 K. From Fig. 1(b), it is found that the effect of the nitrogen addition on the carbon particle agglomeration is relatively weaker than that on the film formation.

In addition to $CH_4$ gas injection to hydrogen plasmas we have installed a carbon particle injector using dc arc plasmas with graphite electrodes. It enables us to study the difference of nitrogen scavenger effects beween $CH_4$ gas and carbon particle injection. Now we are testing the stable arc plasma generation using coaxial graphite electrodes and effective carbon particle injection for graphite film formation was shown in the preliminary experiments.

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

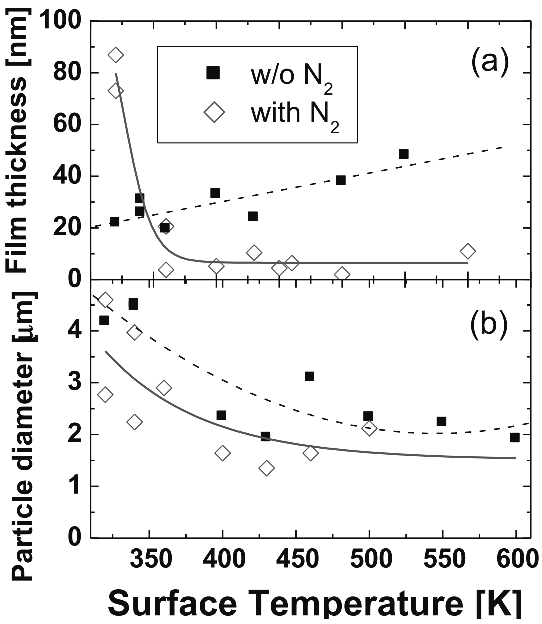


Fig. 1. Surface temperature dependence of film thickness (a) and diameter of single carbon dust particles (b) observed on the target exposed to $H_2/CH_4$ and $H_2/CH_4/N_2$ plasmas for 10 hours. The gas flow rate of $H_2$, $CH_4$, and $N_2$ were 20, 1 and 1 sccm, respectively.