**24P045-P**

# Control of carbon agglomeration and hydrogen retention in low temperature plasmas with H-C-N reactive molecular system[1]

# H-C-N反応性分子を有する低温プラズマ中における炭素凝集と水素吸蔵の制御[1]


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So far, we have studied mechanisms of carbon dust formation using thermo-equiliblium inductively coupled plasmas (ICPs). Experiments were performed with Ar/$H_2$/$N_2$ mixture plasmas. Addition of just a few percent of nitrogen gas to hydrogen plasmas led to significant suppression of carbon dust formation on the graphite target. We have started a new experimental study on SOL plasma-wall interactions, such as suppression of carbon agglomeration and hydrogen retention using steady state, non-equiliblium hydrogen plasmas in Heliotron-DR device. Here results of ICP experiments are reviewed and intial results RF plasma production are shown.


## 1. Introduction

Carbon materials are used for plasma facing components (PFCs) in present fusion experimental devices because of its superiorly high thermal properties. But divertor tiles made of CFC are severely eroded by chemical and physical sputtering of hydrogen. Consequently, carbon redeposit layer and carbon dust particles are generated[1]. Carbon redeposit layer and carbon dusts retain large amounts of hydrogen isotope in a fusion device. This is a main reason why the carbon materials will not used in DT burning ITER. The suppression of tritium retention in the carbon redeposit layer and dust growth is a critical issue for revival of carbon materials as PFC in future fusion reactors. So far we have studied the suppression mechanism of carbon particle growth using thermo-equiliblium ICPs[2]. It is found that the growth of carbon particles are strongly suppressed with a small amount of nitrogen gas injection into hydrogen plasmas[3].

However, ICPs are thermo-equilibrium plasmas, much different from the SOL and divertor plasmas in fusion experiments. A new experimental study to control the carbon agglomeration and hydrogen retention in the carbon redeposit layer is started in Heliotron-DR, where low temperature steady state plasmas of H-C-N reactive molecular system are generated. This report describes a brief review of the dust experiments in ICP and the present status of Heliotron-DR device for PSI experiments.

## 2. Experimental setup

Figure 1 shows a schematic diagram of ICP irradiation system. The electron temperature is ~1 eV. The working gas pressure is ~4 kPa. The atomic and ionic hydrogen fluxes onto the graphite target are ~$10^{23}$ $m^{-2}s^{-1}$ and (2-8)$\times10^{19}$ $m^{-2}s^{-1}$, respectively.

Steady state RF plasmas in Heliotron-DR are produced with a steady state helical magnetic field of 200 G. Closed magnetic surfaces generated by the helical coils contribute to produce homogeneous plasmas in the toroidal direction. Four antennas are placed different toroidal sections and powered by individual RF power source. The total RF power of CW sources is 2.5 kW and a pulse RF source of 10 kW at 200 MHz with a pulse length of 10 ms is also used. The working pressure is around ~ 1 Pa. Electrostatic probes are used to measure electron temperature and density. Mass spectrometry (QMS) and optical emission spectroscopy are used to observe the reactive species in the plasma with H-C-N system.

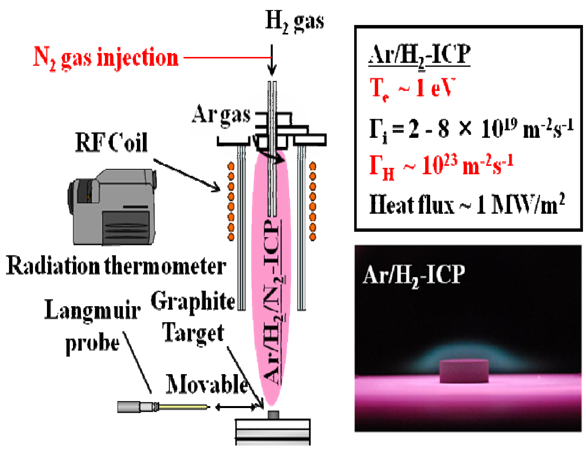


Fig. 1　Schematic diagram of ICPs irradiation system

## 3. Results and discussion

Figure 2 shows the weight loss and average number density of carbon dust particles observed on the graphite target as a function of the surface temperature in ICP experiments. Weight loss and density of carbon dust particles strongly depend on the target temperature as shown in Fig. 2. These experimental results indicate that the dust growth occurs dominantly on the target surface. Figure 3 shows number density and average diameter of carbon dust particles observed on the target as a function of nitrogen injection ratio, target weight loss, and CH, $C_2$, CN and NH emission intensity normalized to Ar I emission. The addition of just a few percent of nitrogen gas to hydrogen plasmas led to significant suppression of carbon dust formation on the graphite target. From optical emission spectroscopy, CN and NH band spectra were observed strongly in $Ar/H_2/N_2$ plasmas. The large increace of CN and NH emission intensity was caused by the production of CN and NH bond formation in stead of CH and C-C bond formation. Since CN and NH bond formation brings to form volatile moleculars, such as HCN, NH*x*, etc., CN and NH bond formation might be a key suppression mechanism of the carbon agglomeration. It is suggested that a small amount of nitrogen injection is a possible method for tritium removal as well as suppression of carbon dust formation in fusion reactors using carbon PFC.

Electron temperature and density at the plasma center are 4-10 eV and $(3\text{-}5)\times10^{16}$ $m^{-3}$ at 2.5 kW RF power, respectively. Electron temperature and density at the plasma edge are 5-10 eV and $(0.4\text{-}1.5)\times10^{16}$ $m^{-3}$ at 2.5 kW RF power, respectively. Hydrogen ion fluxes are $(3\text{-}6)\times10^{20}$ $m^{-2}s^{-1}$. These plasma features are very helpful to study the suppression mechanisms of carbon agglomeration and hydrogen retention in the SOL and remote plasmas in fusion devices.

## 4. Conclusions

Experiments in $Ar/H_2/N_2$ plasma irradiation to graphite material show that nitrogen injection into $Ar/H_2$ plasmas leads to the significant suppression of carbon dust formation with $N_2$ injection ratio of 0-1 %. A new experimental study to control the carbon agglomeration and hydrogen retention in the carbon redeposit layer have been started in Heliotron-DR, where low temperature steady state plasmas of H-C-N reactive molecular system are generated. These results in Heliotron-DR plasmas irradiation are shown in 24P046-P at this conference.

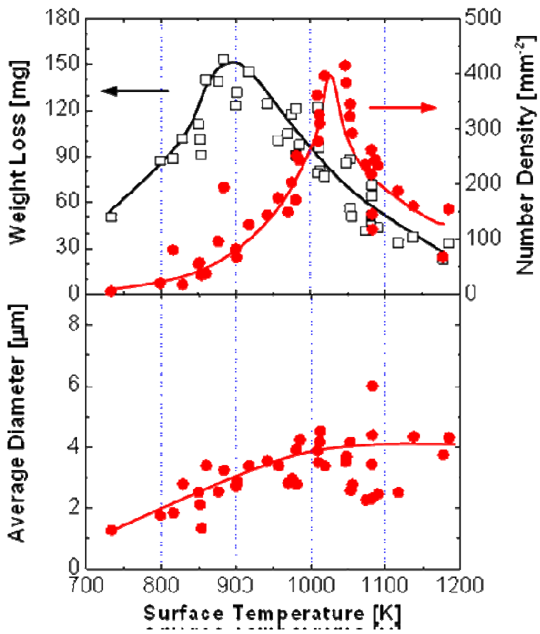


Fig. 2 The weight loss and average numberdensity of carbon dust particles observed on the graphite target as a function of the surface temperature .

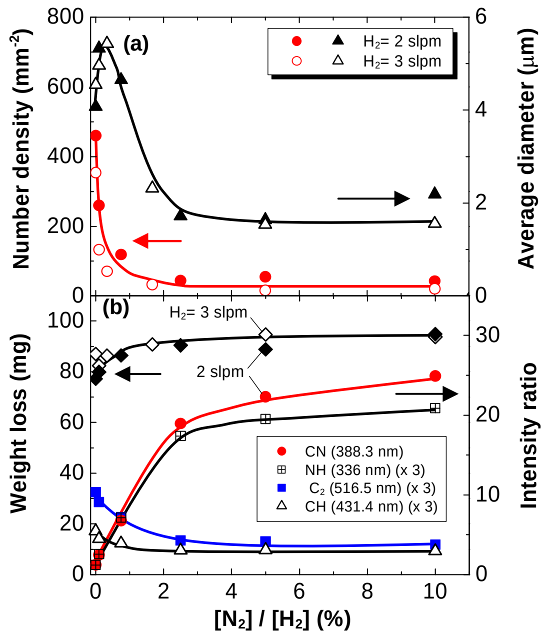


Fig. 3 Number density and average diameter of carbon dust particles observed on the target as a function of nitrogen injection ratio. The lower figure shows the variation of target weight loss and CH, $C_2$, CN and NH emission intensity normalized to Ar I emission

## References


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[3] M. Kyo et al., Plasma Fusion Res. **5**, 004 (2010)