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

Uesugi, Y., Takeguchi, Y., Kyo, M., Tanaka, Y.
(Kanazawa Univ.),
Masuzaki, S., Ashikawa, N., Sagara, A.

Carbon materials are used for the plasma-facing components (PFC) in fusion devices because of their superior thermo-mechanical properties. However, dust particles are formed by plasma–surface interactions in fusion experimental devices. Because carbon dust retains large amounts of hydrogen isotopes, the dust particles in fusion reactors cause safety problems mainly concerning the tritium inventory and chemical reaction with water leading hydrogen release and explosion. The suppression of dust formation is an important issue in future fusion reactors. In this study, we report on experiments conducted to investigate the influence of nitrogen injection into argon/hydrogen plasmas on carbon dust formation by using high-power inductively coupled plasmas (ICP). Nitrogen injection has been considered and tested as one of the methods for tritium and co-deposits removal in carbon PFC. Carbon dust formation in addition to tritium removal efficiency should be studied in nitrogen containing plasmas.

Experiments have been performed in $Ar/H_2/N_2$ mixture plasma irradiation to an isotropic graphite target (IG-430U, Toyo Tanso Co. Ltd.). The working gas pressure is about 4 kPa. The electron temperature is ~1 eV. The atomic hydrogen and ion flux onto the graphite target are $\sim10^{23}\ m^{-2}s^{-1}$ and $(2\sim8)\times10^{19}\ m^{-2}s^{-1}$, respectively in the present irradiation experiments. These plasma features are very helpful while studying the chemical erosion of carbon and the dust formation mechanism in the detached divertor plasma conditions.

The dominant erosion process of the graphite target is due to chemical sputtering by low-energy hydrogen atoms under Ar/H_2 plasma irradiation. Many carbon dust particles are observed on the graphite target eroded by chemical erosion[1]. When nitrogen gas is added to the hydrogen plasmas, the characterisitic feature of the carbon dust formation is drastically modified. Figure 1 shows the number density and size of the carbon dust particles, target weight loss, and optical emission intensity of CH (431.4 nm), C_2 (516.5 nm), CN(388.3 nm), and NH (336 nm) band spectra normalized to Ar I (750.4 nm) emission as a function of N_2 injection ratio into hydrogen, where the N_2 injection ratio is defined as the nitrogen gas flow rate normalized by the sum of nitrogen and hydrogen flow rates. It is found that carbon dust formation is strongly suppressed in the argon/hydrogen plasmas with a small amount of nitrogen gas injection. At increasing nitrogen gas injection ratio, the weight loss of the graphite target increases slightly and the number of carbon dust particles decreases drastically. The size of the dust particles reaches a peak at N_2 injection ratio of 0.1-0.3% and then decreases rapidly with increasing N_2 injection ratio. In addition, the significant appearance in the optical emission from CN and NH radicals is served near the target surface. The CH intensity decreases by ~40% when the N_2 injection ratio is increased from 0% to ~9%, and the C_2 intensity decreases by ~60%. The increase in weight loss is caused by chemical sputtering of carbon by nitrogen atoms, which generates volatile CN, HCN, and C_2N_2, and results in the increase in CN emission intensity. The production of CN and NH radicals by the reactions of hydrocarbon radicals with nitrogen atoms also contributes to the increase in CN and NH intensities. The enhancement of erosion by chemical sputtering by atomic nitrogen is considered as one of the causes for the suppression of carbon dust formation.

With increasing nitrogen gas injection ratio, the carbon dust shape changes into polyhedral particles at an N_2 content of 0.3-0.7% and clusters made of smaller particles at an N_2 content > ~2%. These results show that the injection of a small amount of nitrogen leads to the suppression of the particle growth from agglomeration of fine carbon crystals to single large particles with several μm size. With increasing N_2 injection ratio above ~1%, however, agglomeration process of carbon particles itself is strongly suppressed. There were no or only few dust particles on the graphite surface eroded by Ar/N_2 plasma irradiation. Moreover, C_2 band spectra were not observed during Ar/N_2 mixture plasma irradiation. From these observations, it seems that the increase of the concentration of C species bonded to N results in the interruption of carbon aggregation for an N_2 injection ratio of > ~1%.

1)Takeguchi, Y., et al.:Plasma Fusion Res. **3**(2008)25.

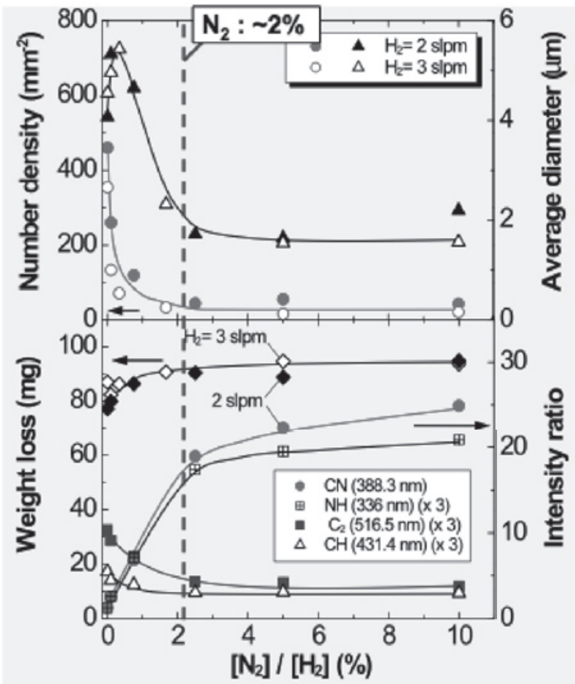

Fig. 1 Number density and average diameter of carbon dust particles observed on the target as a function of nitrogen injection ratio. The lower figure shows the variation of target weight loss and CH, C2, CN and NH emission intensity normalized to Ar I emission.