§73. Study on Generation Mechanism of Carbon Particles Induced by Hydrogen Plasma Wall Interaction

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Formation of particles due to interaction between hydrogen plasma and carbon wall has attracted a great deal of attention in the fusion research, since they pose two potential problems. They remaining in a fusion device are dangerous, as they can contain a large amount of tritium; they may also lead to deterioration of plasma confinement. Thus, clarification of the formation mechanism of particles due to the interaction is necessary for suppressing their formation. For this purpose we have developed a device using ECR discharge.[1)]

The device developed for studying the carbon particle formation was composed of a stainless steel vessel of 267 mm in maximum inner diameter and 294 mm in length, connected to the microwave guide through the quartz window, two magnetic coils, and 2.45 GHz microwave power supply ($P_m \leq 500$ W), and the plasma was generated using an electron cyclotron resonance (ECR) discharge. The magnetic mirror field was generated with the coils, leading to formation of the ECR zone (875 Gauss) around 60 mm away from the quartz window for supplying the microwave power to the reactor. In order to study the interaction between H_2 plasma and carbon wall, a carbon fiber composite (CFC) target of 35 mm in diameter and 8 mm in thickness was placed at 285 mm away from the center of quartz window. An rf voltage of 13.56 MHz ($P_{rf} \leq 200$ W) was applied to the target for controlling its dc sheath potential, that is, controlling the kinetic energy of ions impinging on it.

Langmuir probe measurements show that n_i is 1.0×10^{11} cm^{-3} at a distance from the target z=5 mm and increases slightly to 1.2×10^{11} cm^{-3} at z=180 mm. The T_e is 5 eV at z=5 mm and increases to 8 eV in a region of z=50-150 mm. The values of n_i and T_e were almost constant in the rf bias power range of 0-38 W, corresponding to the CFC target potential V_s of 14-214 V with respect to the plasma potential.

The surface temperature of the CFC target was measured with a thermocouple. The temperature gradually increases from 300 K just after the discharge initiation (t=0 min) to 400 K in 5 min. The steady state temperature is almost the same as the lowest value of the divertor wall temperature, T_{wall}=400-700 K, expected for the large nuclear fusion devices.

Carbon particles trapped with the particle collecting mesh were observed with the TEM. The particles are classified into two size groups: one is the large size group of above 100 nm in size, the other is the small size group of below 30 nm in size. Large particles have an irregular shape which suggests that they are flakes peeled from the carbon films deposited on the reactor wall. Small particles have a nearly spherical shape, which indicates their formation in gas phase as such spherical particles are hard to be emitted from the surface under the conditions of interest.

Figure 1 shows size distributions of small particles for V_s=14, 114, and 214 V. Their average size decreases with increasing V_s, while their size range of 2-24 nm is insensitive to V_s. A total volume of small particles was deduced from the distribution in Fig. 1 using the assumption that they are spherical. Total volumes for V_s= 114 V and 214 V decrease to 60 % of that for V_s=14 V.

Information about atoms and molecules emitted from the target was obtained by optical emission spectroscopy. Emissions from CH and C were observed in addition to those from H and H_2. All the intensities decrease with increasing V_s from 14 V to 114 V, and then they are nearly constant for V_s=114-214 V. Since n_i and T_e are independent of V_s, the V_s dependence indicates the V_s dependence of concentrations of carbon-containing species released from the carbon wall. The V_s dependence is similar to that of total volume of small carbon particles, suggesting that the carbon-containing species contribute to the formation of small particles in gas phase.

Further study under conditions of high n_i (> 10^{13} cm^{-3}) is necessary for revealing the mechanism of particle formation.

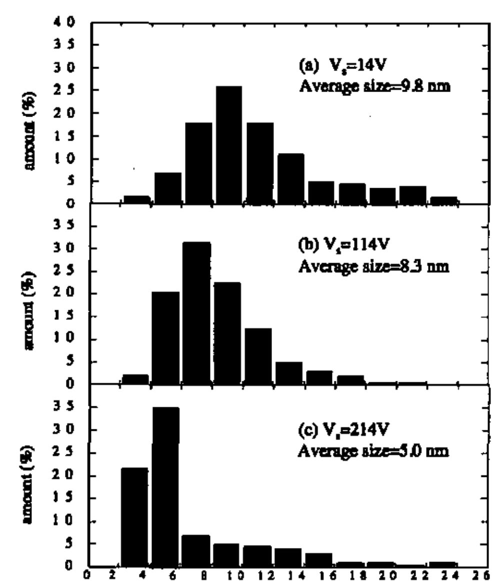

Fig. 1 Size distributions of small particles for V_s=14, 114, and 214 V.

Reference
1) Koga, K., IEEE Trans. Plasma Sci. **32**, (2004) 405.