§3. Study of Carbon Dust Formation and their Structure Using Inductively Coupled Plasmas under Heavy Atomic Hydrogen Irradiation

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Carbon fiber reinforced composites (CFC) are superior materials as the diverter armor tiles of plasma facing components because of high thermal conductivity and high tensile strength. However, sputtering erosion and dust formation of carbon materials bring many significant effects on a fusion reactor, such as tritium retention, impurity release, degradation of vacuum sealing and electrical isolation, etc. At the present the fundamental processes of the dust formation mechanism in the fusion plasmas has not been clarified.

In this paper, high power inductively coupled plasmas (ICPs) [1] with a power level of 10-20 kW are used to study plasma surface interactions and dust formation mechanism. High power ICPs has characteristic features, such as high particle flux (ion flux: $\sim 10^{20}$ $m^{-2}s^{-1}$, atomic hydrogen flux: $\sim 10^{23}$ $m^{-2}s^{-1}$), high heat flux (~ 1 MW/m^2), flexible gas mixtures and so on. Although the working gas pressure is high (P~5 kPa), these plasma features are very helpful to study the carbon erosion and dust formation.

Experimental results in argon-hydrogen mixture (Ar:60 slpm, H2:0~9 slpm) plasma irradiation onto graphite targets are reported[2]. Six graphite (IG-430U) or silicon crystal targets with a diameter of 15 mm are placed at different position to examine how the irradiation condition affects the graphite target erosion and dust formation. Spectroscopic measurements show that the dominant processes of graphite target erosion should be chemical sputtering of graphite by atomic hydrogen irradiation in the present experiment. After 180 minutes plasma irradiation, graphite and/or silicon targets were collected and their weights were measured to have the mass change of the graphite target before and after Ar/H2 plasma irradiation. It was found that significant erosion occurred in the graphite targets facing the plasma (No. 1–3). But, targets placed in the shadow region (No. 4–6) have hardly eroded. The maximum erosion rate was observed in graphite target 1, which was irradiated directly by both hydrogen ions and atoms. The erosion rate decreases rapidly as the targets are away from the plasma. A rough estimation of the chemical sputtering yield by low energy atomic hydrogen irradiation is 0.002–0.005 as shown in figure 5, which is close to those obtained in the energetic beam irradiation experiments and fusion plasma experiments. Here, the chemical sputtering yield is estimated by the weight loss of the graphite target and the hydrogen gas feed rate. Since the electromagnetic fluid simulation of the induction plasma shows that most of the hydrogen molecules introduced into the induction plasmas are dissociated, to be atomic in the core region, the influx of atomic hydrogen is estimated on the basis that the introduced hydrogen particles are fully dissociated in the core plasma and the generated atomic hydrogen particles are carried equally downward along the cross sectional area of the plasma column.

Figures 2(a)~(f) show SEM pictures of dust particles observed on the graphite targets at different locations. It is found that the shape and structure of the dust particles are strongly related to the graphite surface temperature, granular when Ts<~1100K and diamond when Ts>~1100K, and it does not depend on the surface material.

1) Tanaka, Y., et al., Appl. Phys. Lett., **89**(2006)031501.
2) Takeguchi, Y., et al., in Proc. 18th Int. Conf. on Plasma Surface Interactions, PS-10, Toledo, 2008.

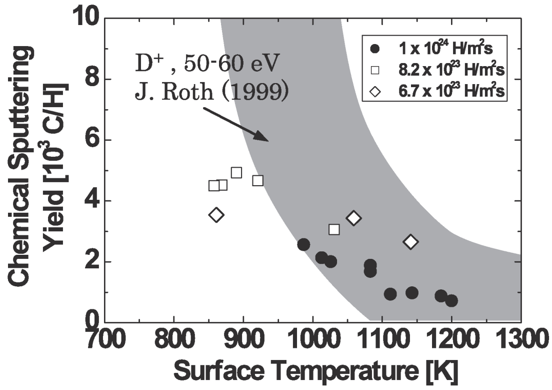

Fig. 1 Temperature dependence of chemical sputtering yield estimated by the weight loss of graphite targets.

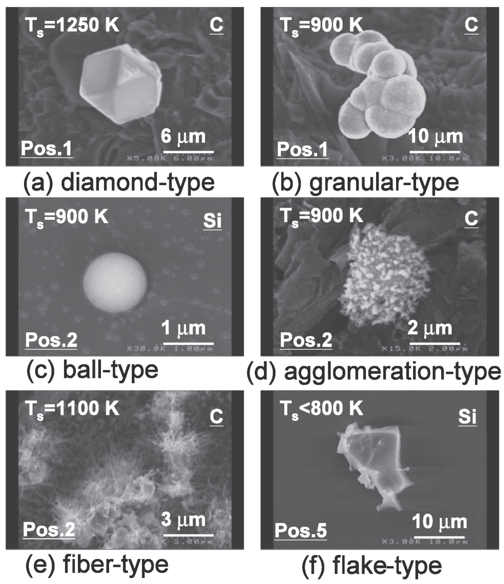

Fig. 2 SEM pictures of carbon dust on the graphite targets and silicon crystal targets.