§40. Effects of Substrate Bias on Dust Flux toward LHD First Wall

Shiratani, M., Koga, K., Uchida, G., Itagaki, N., Kamataki, K., Nishiyama, K., Morita, Y. (Kyushu Univ.)

Much attention has recently directed to the study of dust in fusion devices mainly because dust can pose safety issues related to its chemical activity, tritium retention, and radioactive content [1]. Therefore, it is important to develop a dust removal method. In a preceding study, it has been found that a positively-biased local potential wall removes the most of particles formed in the processing plasmas [2]. The results motivate us to study the collection of dust particles in fusion devices using the local bias potential. Here we report experimental results of dust collection in a divertor simulator and the Large Helical Device (LHD) in the National Institute of Fusion Science using biased substrates as a first step to realize a novel dust removal method for fusion reactor utilizing the local bias potential.

Dust collection in the divertor simulator was carried out using helicon H_2 discharge plasmas [3]. Dust particles were produced due to interactions between a graphite target and the plasmas. They were collected on DC biased Si substrates of 15x10 mm^2 which were set at 110 mm below the graphite target. The collected dust particles can be classified into three kinds: spherical particles, agglomerates, and flakes [3, 4]. The major composition of the dust particles collected is carbon, which is the primary component of the graphite target. We have obtained dependence of particle fluxes of dust towards the biased substrates on the potential difference $\Delta\phi$ between bias voltage V_{bias} and space potential V_s. The spherical dust flux increases exponentially by 2 orders of magnitude with increasing $\Delta\phi$ from -80 V to +20 V, while the fluxes of agglomerates and flakes are irrelevant to the bias voltages. These results suggest transport mechanisms of agglomerates and flakes are different from that of spherical dust particles. The results of spherical dust particles motivate us to carry out collection of dust particles in LHD using local bias potential.

Dust collection in LHD was conducted using DC biased Si substrates located at a bottom first wall during a total discharging period of 920 s of H_2 and He main discharges (the 15th campaign on 11th and 12th August, 2011). The mean size and size distribution of dust particles in LHD is similar to that in the divertor simulator. The major composition of the dust particles is carbon, which is the primary component of the divertor plates in LHD (IG-430), whereas flakes contain Fe and Cr, which are the main components of its first wall (SS316). Figure 1(a) and 1(b) show dependences of particle and mass fluxes of dust on $\Delta\phi$. The spherical dust flux increases exponentially by 1.5 orders of magnitude with increasing $\Delta\phi$ from -70 V to +70 V. The size distribution of spherical dust particles is well expressed by the power law distribution [4]. The number density of the spherical dust particles increases with decreasing their size. Taking into account of the spherical dust particles below the lower detection limit of SEM, the flux of the spherical dust particles is much larger than that as shown in Fig. 1(a). The particle flux of flakes increases by 1 order of magnitude with increasing $\Delta\phi$ from -70 V to 0 V and then it is nearly constant in a $\Delta\phi$ range of 0 V to +70 V. Agglomerates in LHD are rare. The results suggest that the electrostatic force drives spherical particles and flakes which are charged negatively. As shown in Fig. 1(b), the mass flux of the spherical particles and the flakes changes in the same manner as the flux but that of the flakes is larger by about 2 orders of magnitude than that of the spherical particles. The removal of flakes is also important from a view point of the mass because the safety limit of global dust inventory in ITER is set at 1 ton [5].These results suggest that the collection efficiency depends on the shape or size of the dust particles.

In conclusion, flux control of dust particles using local bias potential is useful to remove carbon and metal dust particles at the shadow area in fusion devices while the collection efficiency depends on the shape or size of dust particles.

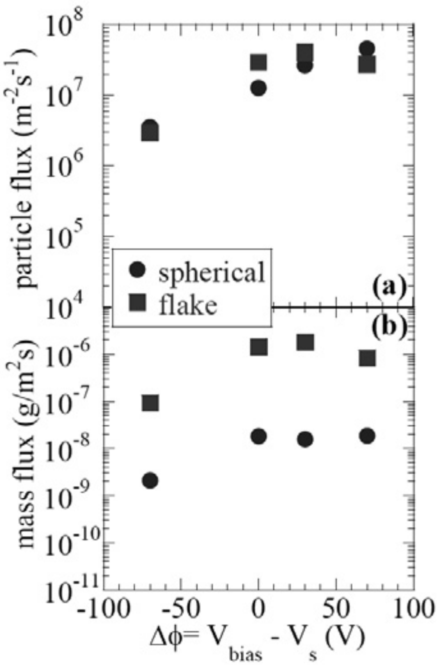

Fig. 1. Dependence of (a) particle flux and (b) mass flux of dust collected in the LHDon the potential difference $\Delta\phi$ between bias voltage V_{bias} and space potential V_s.

[1] S. I. Krasheninnikov, et al., Plasma Phys. Control. Fus. 50 (2008) 124054.
[2] Y. Kurimoto, et al., Thin Solid Films 457 (2004) 285.
[3] S. Iwashita, et al., J. Plasma Fusion Res. SERIES 8 (2009) 308.
[4] K. Koga, et al., Plasma Fusion Res. 4 (2009) 34.
[5] J. Roth, et al., J. Nucl. Mater. 390-391 (2009) 1.