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Collection of Carbon Dust Particles Formed Due to Plasma-Wall Interactions Between High Density H_2 Plasmas and Carbon Wall onto Substrates by Applying Local DC Bias Voltage

高密度水素プラズマとカーボン壁間のプラズマ・壁相互作用により形成されるカーボンダスト粒子の局所バイアス電圧印加による捕集

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We collected dust particles generated by interaction between a plasma and a carbon target in helicon discharge reactor, by which diverter plasmas in fusion devices are simulated. The dust particles are classified into three kinds: small spherical particles, agglomerates, and large flakes, suggesting three formation mechanisms: chemical vapor deposition (CVD) growth, agglomeration, and peeling from redeposited layer on the reactor wall. The area density and flux towards substrates of dust particles exponentially increase with the substrate bias voltage. The energy influx of plasmas towards the target and ion density were measured to clarify the dust formation mechanisms. They are nearly constant irrespective of the substrate bias voltage suggesting that the production rate of dust particles does not depend on the substrate bias voltage and their collection efficiency does.

1. Introduction

Dust particles are formed in fusion devices due to plasma-surface interactions. Dust particles pose potential problems for the safety of future fusion devices, as they can accumulate tritium and may explode violently, and they have health and environmental risks of spreading of dust particles that contain tritium. Dust particles are also known that they lead to deterioration of plasma confinement in future fusion devices [1]. We have found large amount of carbon nanoparticles formed due to interactions between hydrogen (H_2) plasmas and carbon walls in the large helical device (LHD) and in our helicon discharge reactor [2, 3]. Here we describe experimental results of collection of dust particles on substrates by applying dc bias voltages to the substrates and measurement results of energy influx towards a target using a calorimetric probe in the helicon discharge reactor.

2. Experimental

Experiments were carried out with a helicon discharge reactor as shown in Figure 1. Dust particles formed due to interaction between H_2 plasmas and a graphite target. Gas of H_2 was supplied to the reactor and the pressure was 5

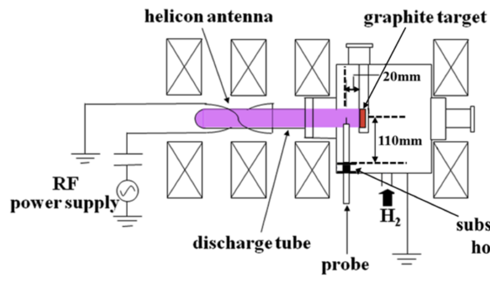

Fig. 1. Experimental setup.

mTorr. H_2 plasmas were generated by applying 1.1 kW, 13.56 MHz pulsed RF voltage to a helicon antenna. The graphite target was located at the center of the discharges. These particles were collected on Si substrates which were set on a holder located at 111 mm below the target. A dc bias voltage was applied to some of the Si substrates during the collection. The total discharging period was 600 s for the collection. The plasma parameters were measured with a Langmuir probe, and energy influx were measured with a calorimetric probe [4]. Then, size and shape of dust particles were obtained with a SEM.

3. Results and Discussion

Dust particles collected are classified into three kinds: small spherical particles, agglomerates, and large flakes, suggesting three formation mechanisms: CVD growth, agglomeration, and peeling off from wall. The size ranges of dust particles are below 1 µm for small dust particles, 100 nm to a few µm for agglomerates and over 1 µm for large flakes. These features are similar to those of dust particles collected in LHD [2, 3].

Figure 2 shows substrate bias voltage dependence of area density and flux towards substrates of dust particles in the helicon discharge reactor. The area density and flux of spherical particles exponentially increase with the substrate bias voltage, while those of agglomerates and flakes are almost constant. These results imply that the flux of dust particles can be controlled by the substrate bias voltage.

Figure 3 shows influence of substrate bias voltage on the energy influx of H_2 plasma measured with the calorimetric probe. The value of energy influx is approximately from 10 to 12 W/cm^2. The energy influx is nearly constant irrespective of the

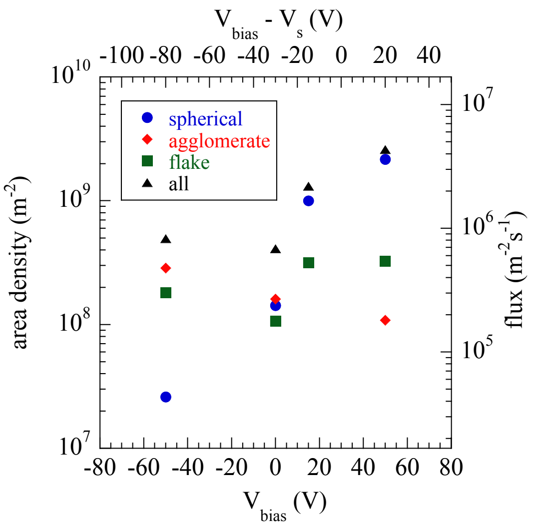

Fig. 2. Substrate bias voltage dependence of area density and flux of dust particles.

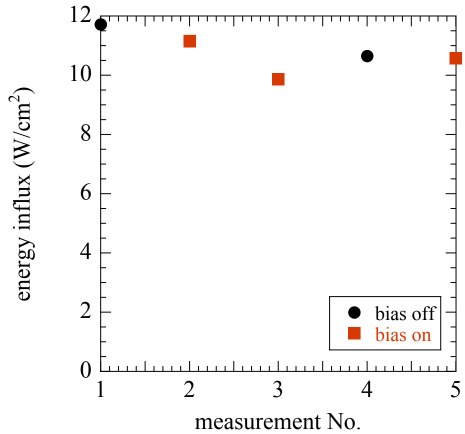

Fig. 3. Influence of substrate bias voltage on energy influx towards the target.

substrate bias voltage. This result is consistent with the results of ion density measured using a Langmuir probe. The substrate bias voltage, therefore, has little effects on plasma parameters and hence the production rate of dust particles. Hence, the collection efficiency of spherical dust particles exponentially increases with the substrate bias voltage.

4. Conclusions

We collected dust particles in the helicon discharge chamber. There are three kinds of dust particles: small spherical particles, large flakes, and agglomerates. They are formed by three formation mechanisms: CVD growth, peeling off from wall, and agglomeration. The flux of dust particles towards substrates exponentially increases with the substrate bias voltage. These results suggest that the flux of dust particles can be controlled by substrate bias voltage. The substrate bias voltage has little effects on the energy influx to the substrate.

Acknowledgments

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