§39. Behaviors of Fine Particles in Plasmas

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1. Introduction

In order to understand the behaviors of fine particles of micron size, charged negatively in plasmas, we have established several experiments in this financial year. First, we have for the first time demonstrated the formation of positively charged fine particles in a cross-field sheath between magnetized double plasmas. Secondary, we have for the first time established the method of fine particle control by using external forces. The particles are transported by the average force induced by time-varying external force. Finally, we have demonstrated for the first time to produce a parallel-plate rf plasma that plasma density can be reduced as low as possible by employing a coaxial rf electrode. This technique is crucial for producing a fine particle cloud with no void inside.

2. Experimental methods and results

2.1 Formation of positively charged fine particles

Here, double plasmas are produced along the horizontal magnetic field by dc discharges with different anode potential and separated up and down in the vertical direction by a cross-field sheath of 12-mm thickness. The anode potential of the upper-side plasma is grounded, while dc bias voltage V_a can be applied to the anode of the underside plasma. When $V_a > 0$, we can produce electric field directed upward in the cross-field sheath region. In order to avoid a mixing of both plasmas, the horizontal magnetic field of $B = 0.5 - 1.5$ kG is applied in the whole experimental region. In this configuration we have succeeded to levitate positively charged fine particles and clarified their basic properties.

2.2 Particle control using time-averaged external force

Since particles have huge mass compared to the ions and electrons, the particles cannot respond on a time-varying force unless the frequency is extremely low. If the frequency is high, the particles follow only a time-averaged force. We utilize this property of fine particles for the control of particle position in the plasma. Here, external force contains the electric force and the ion-drag force. We call this technique time-averaged particle driving (TAPD) method. The TAPD method is very useful for controlling the positions of the particles levitating in the plasma. Especially, the TAPD method works for producing a fine particle cloud without a void inside.

We induced these forces externally by placing two point electrodes in the plasma center. Alternative potential is applied to these electrodes. Then, the particles feel these average forces and transported to a fixed position between the electrodes. We have observed for the first time a particle cloud without a void inside by employing this method in a parabolic-flight experiment.

2.3 Coaxial weak plasma production

In order to create a fine particle cloud without a void inside an extremely weak density plasma has to be produced because of the reduction of ion drag force. In this case if we decrease a discharge power, however, the discharge itself would stop before decreasing the plasma density sufficiently. To avoid this phenomenon, the experimental region is divided into two parts. One is particle levitation region where the plasma density can be reduced as low as possible without the limit of discharge stop, and the other is plasma sustaining region where the discharge can continue even when only a low input power. The plasma density in the center region can be reduced as low as possible owing to the shift of discharge region towards the periphery. In this way, we can produce very low-density plasma in which the fine particle cloud can be levitated without a void inside. This result is verified by the parabolic experiment.

References

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