§ 36. Behaviors of Fine Particles in Plasmas

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Fine particles of micron size, charged negatively in plasmas, are confined under the balance between electrostatic and gravitational forces. Since Coulomb coupling parameters G is large, the particles reveal various characteristic behaviors concerned with a strongly coupled state. In our previous experiments it was demonstrated that the externally applied electric and magnetic fields drove a collective motion of particles. In this research we clarify the dynamic properties of fine particles under the microgravity condition [1-4].

The microgravity experiment is performed in a parabolic flight of the aircraft MU-300, Diamond Air Service Co Ltd., Japan. The experiment is carried out inside a vacuum chamber of 11.6-cm wide, 15-cm height and 11.6-cm long. Two side walls contain square view windows of 8 cm × 8 cm in length for laser beam injection and observation of right-angle scattering from the fine particles, respectively. The plasma is produced by using two experimental configurations, i.e., Setup A for a parallel plate RF discharge and Setup B for a grid-cage RF discharge. Fine particles of 10 μm in diameter made from acrylic balls are supplied by a particle dispensor. The fine particle dispenser is movable in radial direction by a linear motor drive.

Before attaining microgravity, plasma discharge is switched on and then the particle dispenser is inserted into the plasma center (Setup A) or the cage center (Setup B). Fine particles are spattered by vibrating the dispenser after achieving microgravity. Then the dispenser is drawn out immediately from the plasma region to the side wall port. The gas used is argon and a mass flow regulator controls its flow rate. Working gas pressure is set in the range of 50 mTorr – 1 Torr and the RF power is varied in the range 1 - 3 W. Just before microgravity gas feed valve and evacuation valve are closed to minimize gas flow inside the vacuum chamber during the microgravity. Fine particles inside the plasma are illuminated by laser sheet beam. Therefore, almost all cross-sectional structure of fine particle cloud between both electrodes (Setup A) and the central part of the grid cage (Setup B) can be observed by CCD video cameras.

In the case of the experiment using the Setup A, fine particles are distributed forming a fine particle cloud around the plasma center just after t = 0 sec. Then, fine particles start expanding both in radial and axial directions between the parallel electrodes. The particle group expanding in radial direction is separated into small groups of particles called "particle-plasmoid" which is moving outward with almost constant speed. As the number of fine particles trapped in the plasma center decreases, a more ordered structure comes out, i.e., a formation of a spherical void inside the particle cloud.

The void structure is very stable. The void diameter is about 1.7 cm. Fine particle density at the boundary is high and a spherical shell surrounding the void appears with thickness less than 2 mm that is corresponding to several layers of the Coulomb lattices. However, fine particles outside region are unstable. We still observe fluctuations of fine particle cloud travelling radially outward at t = 11 sec.

Similar measurements are performed in the experiments using the Setup B with a spherical grid cage. Fine particle dispenser is completely drawn out at t = 0 sec from the grid cage through a hole made on the side wall of the cage. Fine particles are initially concentrated at the cage center, distributing with an extremely distorted cloud structure. However, these fine particles start to form finally a symmetrical spherical structure at the center. During this evolution we did not observe oscillations and instabilities as in the Setup A. No void is observed inside the particle cloud. Therefore, it turns out that the grid cage discharge is very important to create a condensed fine particle cloud in plasmas.

The fine-particle behaviors have also been analyzed by computer simulation, where formation of Coulomb crystal and vortex were investigated [5,6].

References

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