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Instability and vortex formation in high speed dust flow in plasmas

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In the space, dusty plasmas are frequently observed in the tail of comets, planet rings, and interplanetary region. The ejecting dust from the surface of the moon by the impact, for example, will be charged up to form dusty plasma in high altitude region. The birth of the star may be also related with growth and coagulation of dusts under the influence of the gravity and space plasma. In this report we intend to investigate the dynamic phenomena of the dust cloud flowing in the plasma with high speed. The dusty shear flow excites the instability, and as a result vortices are formed in the nonlinear state.

In the experiment we introduce dusts with a diameter of the orders of micrometer. Such small particles are usually charged negatively due to the large electron mobility in plasmas. Under such circumstances, various characteristic phenomena concerned with a strongly coupled state of dusty plasmas, such as formations of Coulomb crystals, dynamic motions of Coulomb fluids, and various wave phenomena, have been reported. By employing a completely dc-discharge plasma, it becomes possible to control the behavior of fine particles more systematically. The effects of vertical magnetic field on the fine-particle behaviors were also investigated and a rotational motion of fine-particle cloud has been observed.

Here, in order to drive high-speed dusty flow we employ a neutral drag force due to the ejected argon from a gas nozzle with small diameter less than 1 mm. The gas ejected from the nozzle gives momentum locally to the particles, which thus eventually drive the directed dust flow. The dusty particles are introduced just above the levitation electrode, which is inserted in the plasma. We can produce duty plasma in the sheath edge region between the plasma and the levitation electrode placed in the horizontal plane. By adjusting the direction of the nozzle we can generate the dusty flow with a velocity which can be precisely controlled by changing the argon flow rate through the nozzle.

First, we place a small column of 0.8 mm in diameter and 3 mm long vertically in the dust flow on the horizontal levitation electrode. We observe dynamic behaviors of dusty flow around the column. Just before arriving at the column the dusty flow is separated into two local flows at the sheath edge in front of the column. In the down stream region these flows are finally emerged into one flow behind the column. Here, we find characteristic phenomena concerned with the Coulomb fluid in the strongly coupled state. In the stagnant region of the dust streams, which is generated around the merging point of the two flows, we clearly observe formation of Coulomb crystal, since the particles in this region are regularly arranged. However, in the boundary region between the stagnation and streaming regions, these particles are strongly interacting with the particle moving along the dust flow. We observe a stochastic fluctuation near the boundary region between the fluid and crystal layers. We will also report the instability and the formation of vortices in the dust flow with large velocity shear. It is considered that the shear viscosity of the Coulomb fluid plays an important role on the onset of the instability and vortex formation.