Effect of background gas composition on dynamic and transport properties of plasma-dust formation

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In many potential applications background component of dusty plasma represents binary or multi-component mixture of noble gases. Previous study of dusty plasmas in mixtures of heavy and light gases [1,2] showed the possibility of strong anisotropy of the function of ion velocity distribution in a strong electric field of gas discharge in presence of significant heating of the ions and large difference between the atomic weights of ions and atoms, the possibility of very. Since the kinetic properties of ion flow play an important role in shaping the parameters of dust formation in the gas-discharge plasma, the choice of the mixture can vary the characteristics of dust formation.

In order to investigate the influence of background gas composition we performed a series of experiments in DC glow discharge setup earlier described in [3]. Dust structures were formed by insertion of spherical glass particles with diameters of 2-5 micron into plasma bulk. Discharge current is held constant during the experiment whereas the pressure of background gas (pure helium; pure argon; mixture of helium (77%) and argon (23%)) was varied within $0.09 \div 1.5$ torr range.

Discharge current as function of pressure of DC discharge in pure helium, pure argon, as well as their mixture is shown in Fig. 1. For all cases the function has a pronounced maximum and decreases at higher pressures. It is known that such behavior is related to free electron mean path and the corresponding average velocities and energies that electron gains between subsequent impacts with background gas atoms.

The depicted diagram is also a convenient tool for characterization of structural properties of dust formation that are located in the stationary striation of DC glow discharge, as such striation can be observed only at certain set of discharge parameters, which closely related to ionization energy through electron impact.

Dashed areas in Fig. 1 correspond to pressure range where very stable striations are observed for every gas combination along with stable crystalline-like structure of dust particles. As expected, the curve for the mixture of gases lies between the curves corresponding to the pure gases. Experiments with different compositions of helium and argon (reported elsewhere) confirm the observed dependence of stable dust structure formation on discharge parameters.

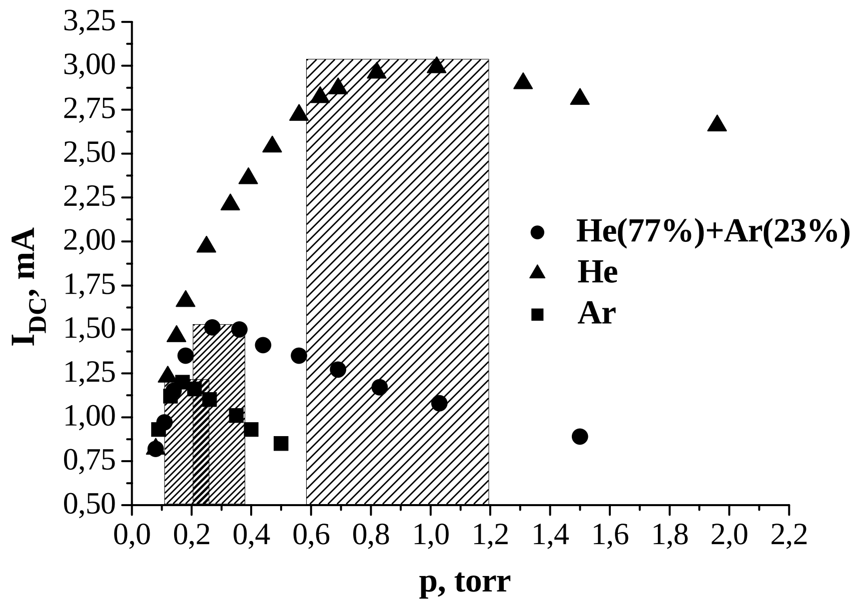

Fig 1. Discharge current as function of pressure of DC discharge in pure helium, pure argon, as well as their mixture.

In Fig. 2 pair correlation functions of dust particles for different gases in DC glow discharge are shown. Discharge current for each case is chosen so that the combination of discharge current and pressure correspond to the dashed area from Fig. 1 for given gas. One can see that crystalline-like dust structures in the mixture of helium (77%) and argon (23%) are observed at pressures around p = 0.27 torr. In pure gases (helium and argon) stable dust structures are not observed at this pressure region.

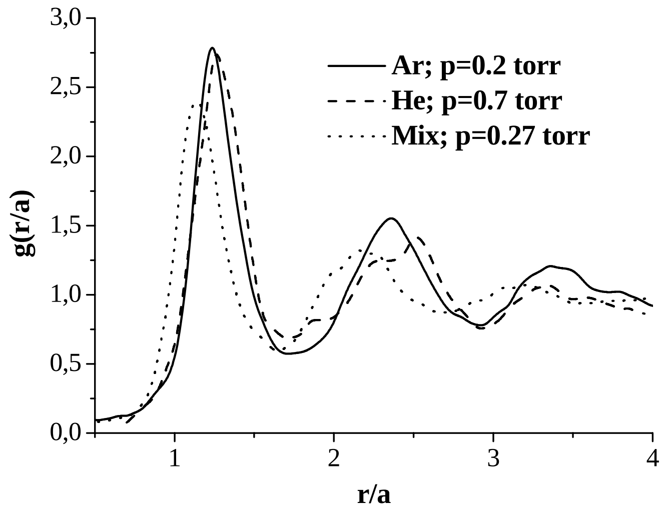

Fig 2. Pair correlation function of dust particles in pure helium, pure argon, as well as their mixture.

Also, this effect can be observed on the basis of axial velocity distribution of dust particles in different gases as shown in Fig. 3. At background pressure p=0.44 torr, the half width of such distribution for dust particles in mixture of helium and argon is narrower that one in pure helium. The same effective temperature (or same velocity distribution) is achieved if the pressure of background gas is elevated to p=0.75 torr.

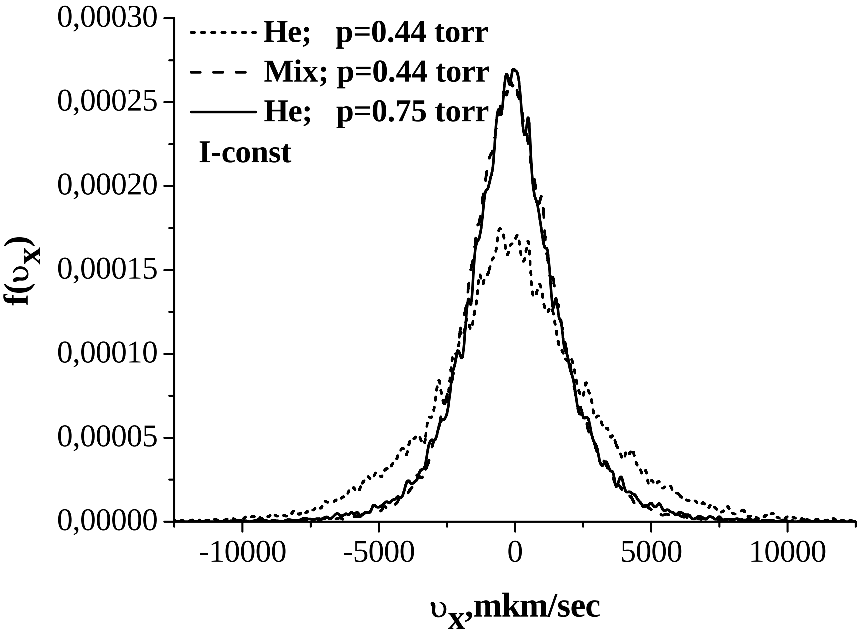

Fig 3. Axial velocity distribution of dusty particles

for pure helium at pressures 0.44 torr and 0.75 torr; and helium – argon mixture at 0.44 torr.

In Fig. 4 horizontal plane velocity correlation function is shown as function of correlation time for pure helium at 0.75 torr and helium and argon mixture at pressure 0.44 torr. Despite the same "effective" temperature of dust particles under chosen condition (Fig. 2), their transport properties are obviously different which indicates the presence of different interaction mechanism of energy transfer between dust particles and background gas/plasma.

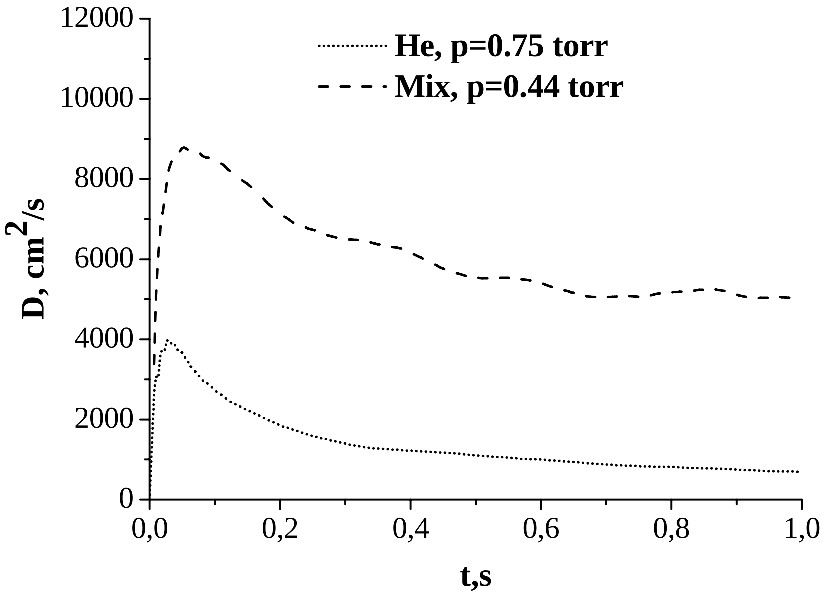

Fig 4. Diffusion coefficient of dust particles in DC discharge

The above discussed measurements indicate that background gas composition has a pronounced impact on the structural and transport properties of dust formation in DC glow discharge. Further investigation is required to determine major physical mechanism of dust – plasma interaction in case of heavy and light gas mixtures of noble gases.

This work was supported by the Ministry of Education and Science of Kazakhstan under grant EP-10/2012.

References

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