The Influence of Gas Mixture on Plasma-Dust Structures in RF Discharge

S.K. Kodanova[1)], M.K. Dosbolayev[1)], T.S. Ramazanov[1)], N.Kh. Bastykova[1)], A.U. Utegenov[1)] and S.A. Maiorov[2,3)]

[1] *Institute of Experimental and Theoretical Physics, Al-Farabi Kazakh National University, Al-Farabi 71, Almaty, 050040, Kazakhstan*
[2] *Prokhorov General Physics Institute, Russian Academy of Sciences, Vavilov st. 38, Moscow, 119991, Russia*
[3] *Joint Institute for High Temperatures, Russian Academy of Sciences, Izhorskaya st. 13/19, Moscow, 127412 Russia*

The gas mixture discharge has a number of features which can appear in experiments with dusty plasma. For example, in the case of a significant difference in atomic masses of ions and atoms, strong anisotropy of the distribution function over ion velocities takes place, which in turn can cause a significant change in properties of dust structures. In this work, the influence of a mixture of gases on plasma-dust structures in the radiofrequency discharge has been studied. The results of numerical simulation of ion and electron drift in the mixture of helium and argon are presented. It is shown that even one percent of argon admixture to helium produces such an effect that argon ions become the main components of the discharge, as they drift with lightweight helium forming a strongly anisotropic velocity distribution function.

1. Introduction

Drift in the strong field can be accompanied by significant heating of ions. A strong anisotropy of the distribution function of ions is possible in the case of a large difference in atomic masses of ions and atoms. This strong anisotropy of the distribution function of ions can cause a significant change in properties of dust structures in plasma. The experiments with dusty plasma in the mixture of gasses were proposed [1-5].

The influence of the wake field on the structural properties of dusty plasma was investigated [6-8]. To study the role of the ion flux (focus) in formation of the vertical chain of dust particles the authors used a special trap in the discharge of a homogeneous gas.

A small admixture to the working gases leads to a very significant change in the characteristics of both the electronic and ionic components of the plasma. Moreover, the characteristics of the gas discharge can be highly in even at very small concentration of impurities. This fact is used in many technical applications of gas discharges, such as gas lasers, plasma display panels, plasma etching reactor and processing of semiconductor materials, light bulbs and flash etc.

2. Results of Experiments

2.1. Experimental setup

The experiments were carried out in a conventional gas discharge setup. The main part of the experimental setup was the electrode system producing a high-frequency capacitive gas discharge. Disk electrodes of 100 mm diameter were placed parallel to each other in the horizontal plane at a distance of 30 mm. The upper electrode was grounded and had a small hole used for dust injection into the plasma and for video-shooting. The dust particles were illuminated by a 0.4mm laser knife, which enabled experimenters to obtain cross sections of plasma–dust structures. In the experiments hollow spherical dust particles of average diameter of 20-40 microns were used.

2.2. Experimental results

To study the dependence of interparticle distances and pair correlation distribution functions of dust particles on gas pressure and gas percentage, the experiments with pure gases, i.e., helium and argon, and argon mixture at a content of 3% were performed. Figure 1 shows pair correlation functions for dust particles $g(r/a)$ (a is the Wigner-Seitz radius), which determine the relative probability of finding a particle at a distance r from the other particle. It means that by the value of the ratio between the first and the second peaks it is possible to determine the type of bond between particles. As we can see from figure 1 dust particles have a liquid-crystal structure in the mixture of He+Ar(3%), whereas under the same conditions in the helium plasma the dust has gaseous structure.

In figure 2 the dependence of the average distance between particles on the gas pressure is presented. The distances between the closest particles are determined by the analysis of the pair correlation function. It is shown that an increase in gas pressure most strongly affects the distance between dust particles in the chain of the discharge in the mixture.

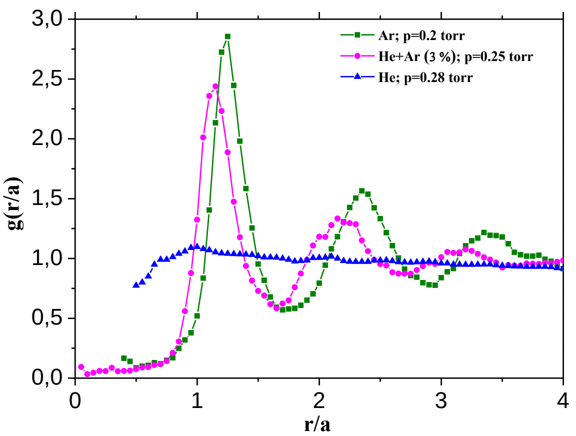

Figure 1 - Pair correlation functions of dust particles in pure argon (square), in pure helium (triangle) and in the mixture of helium (97%) and argon (3%) (circle).

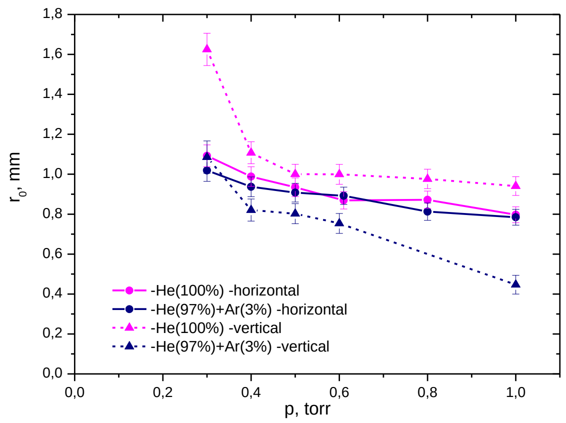

Figure 2 - The average distance between the nearest particles as a function of gas pressure in the horizontal and vertical planes in pure helium and helium-argon mixture.

3. The Results of Numerical Simulation of Ion and Electron Drift

The calculations of ion and electron drift were performed using the Monte Carlo method similar to that used in [1-2]. After each collision, the electron equation of motion in the constant field was integrated and, according to known cross sections of elastic and inelastic processes, the probability of either event was determined.

The most interesting and important fact from practical point of view is a strong increase in the frequency of ionization at low addition of argon. In this case, most argon atoms are ionized; hence, the discharge will mainly contain argon ions. The results of these calculations suggest a strong influence of gas composition on dust structures in discharge plasmas, making it possible to predict their characteristics due to a supersonic flow regime (Mach cone, anisotropy of interaction between dust grains, etc.).

4. Conclusions

In this paper we present the results of experimental and simulation studies of the influence of plasma composition on the structural properties of plasma-dust formations.

The results of experimental studies of dust structures in the RF discharge plasma in the mixture of two types of gases, “light” He and “heavy” Ar, have been analyzed. It has been found that the admixture of a small amount of argon (3%) to helium causes an increase in the interaction anisotropy of dust particles, which is most clearly expressed in a large difference in distances between dust particles in the chain and between chains.

The numerical results show that the ion composition in the discharge is mainly represented by argon ions even if there is only one percent of argon in helium. The drift of argon with lightweight helium gives a strongly anisotropic velocity distribution function.

5. References

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