Electric probe measurements of temperature of electrons of dusty plasma in mixture of noble gases in RF discharge

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In this work the results of studying of the electron temperature of buffer and complex plasmas in mixtures of noble gases (helium + argon) in capacitively coupled radiofrequency (CCRF) discharge are presented. The axial distribution of electron temperature in the inter-electrode gap has been measured. Measurements have been made using an RF compensated electric probe. The comparison of the experimental results shows that admixture of a small amount of argon to helium leads to a decrease in the electron temperature of buffer plasma. The presence of dust particles in the plasma causes an increase in the electron temperature.

1. Introduction

Dusty (complex) plasma is the usual low-temperature plasma which contains small solid particles, ranging in size from tens of nanometers to several hundred micrometers [1,2]. Dust particles in the plasma acquire a charge equal to a few tens of thousands of elementary charge and can be ordered to create plasma dust structures. Diagnosis of low-temperature dusty plasmas using traditional methods is of great interest and the results shows that the presence of dust particles significantly affects the basic properties of the background plasma. As well, the addition of the impurity gas in the main gas leads to significant changes in the structural and dynamic properties of plasma-dust formations [3,4]. To explain such a behaviour of plasma-dust structures in the background plasma of gas mixture it is necessary to know the main characteristics of the discharge such as the electron temperature under different experimental conditions and its changes with the addition of heavy argon to the helium gas. The results of studies of the axial distribution of the electron temperature in the complex plasma in mixtures of noble gases obtained by the electric probe method are presented. The probe method makes it possible to determine the local electron temperature in the discharge gap and to detect its change in the interelectrode volume.

2. Experimental setup

The experiments were carried out in the plasma of radiofrequency capacitive discharge. The main part of the experimental setup is the electrode system, where a high-frequency gas discharge is formed. The electrodes are located parallel to each other in a horizontal position. The distance between the electrodes is 30 mm. The RF compensated single electric probe is inserted into the plasma and connected to the measuring circuit through the multicontact connector in the vacuum chamber. The probe has a compensating aluminium electrode and LC resonance filters for the first and second harmonics of the RF field. The contacting part of the probe has a diameter of D = 0.12 mm and length L = 3.3 mm. Argon, helium gases and their mixtures were used as a working medium. As dust particles we used polydisperse Al_2O_3 particles and monodisperse particles of melamine formaldehyde of a size of 10 mkm.

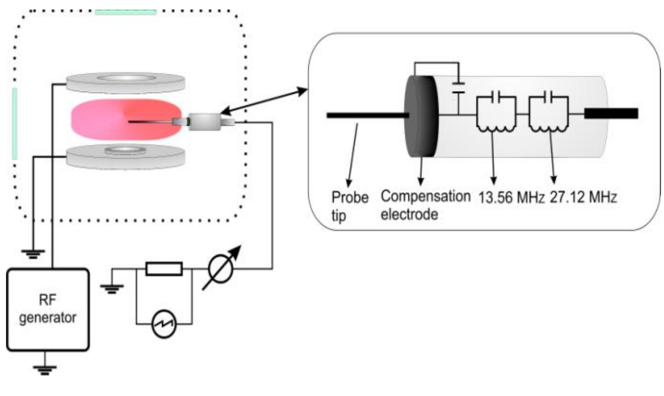

Fig.1 The experimental setup

3 Results

The temperature distributions of electrons in the axial direction in the buffer plasma of pure He and He + Ar mixture were determined using the Langmuir probe. The electron temperatures were measured in the range from 6 mm to 26 mm from the lower RF electrode 2 mm. The increase in the temperature of electrons in the sheath of the discharge can be explained by stochastic heating and acceleration of electrons in the RF field near the electrodes [5]. By adding argon (3%) in helium (97%), the electron temperature is reduced throughout the discharge gap. This is due to the ionization potentials and ionization cross sections of atoms of these gases. The ionization potential of argon is less than that of helium, also the ionization cross section of argon is large, therefore argon atoms are ionized more intensively at the same discharge power. In this case, the electron temperature decreases due to frequent inelastic collisions with atoms of plasma-forming gases.

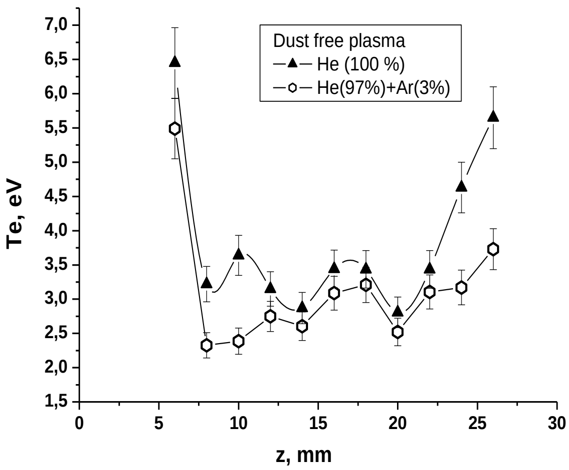

Fig. 2 The axial distribution of the electron temperature in the interelectrode volume in pure He and He + Ar. The pressure in the discharge chamber is 0.3 Torr, the power is 20 W.

The temperature distributions of plasma electrons in the dusty plasma of pure helium and mixtures of helium and argon were determined. After inserting the probe in the discharge gap, a positive space-charge layer was formed around it. The same behaviour of dust particles in the probe region in the glow discharge and in the radio-frequency discharge under microgravity conditions were described in [6-8].

The experiment showed that the electron temperature increased in the presence of dust particles in the plasma. An increase in the energy of electrons after injection of dust particles under the same discharge conditions was described in [9, 10] and obtained by numerical simulations [11]. Figure 3 shows the temperature distributions of electrons and the buffer dust plasma in mixtures of helium and a small amount of argon.

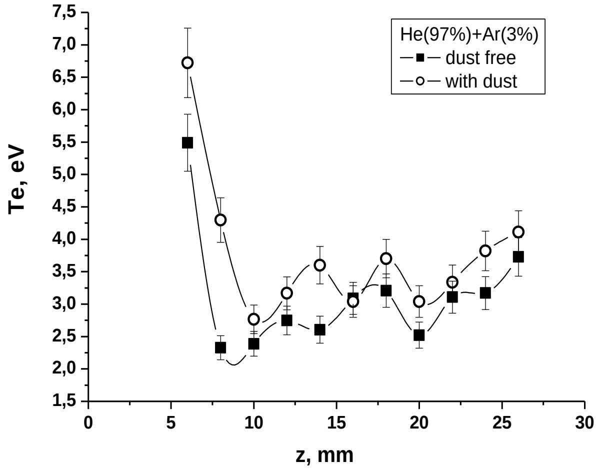

Fig. 3 The axial distribution of the electron temperature in the interelectrode volume in He + Ar mixture without dust particles and with dust particles. The pressure in the discharge chamber is 0.3 Torr, power is 20 watts.

3. References

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