Optical properties of the dusty plasma in RF discharge

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The paper presents results of experimental research of the optical properties of high-frequency capacitive discharge argon plasma with particles. Based on the analysis of the spectral lines the effect of dust component on the plasma emission intensity was investigated. The plasma glow intensity was measured as a function of dusty particles density. It was shown that the increase in dusty particles density leads to increase in glow intensity. The results of this work can be used for development of a non-contact method of the plasma-dust structures diagnostics.

Introduction

Dusty plasmas is ionized gas containing micron-sized solid particles. The study of the dusty plasmas physical properties is of great interest because it has practical application in creating of composite nanomaterials, for microelectronics, space technology, in fusion processes [1-5].

Dust particles are introduced into the plasma environment, or appear as the result of erosion of the electrodes or wall material, they become electrically charged. Due to the high electron mobility dust particles tend to acquire a negative charge (about 10^4 elementary charges). The large charge of dust particles, which determines strong interaction between them, leads to the formation of the ordered structures, so called Coulomb crystals [1-8].

The study of dusty plasma optical properties is an important scientific problem, since it allows to obtain extensive information about the dusty plasma parameters plasma temperature and plasma density and to achieve deeper understanding of physical processes in the system. In this paper, optical properties of dusty plasma created in high-frequency capacitive discharge (RFCD) of argon gas were investigated by the optical spectrometric analysis of plasma glow. The peculiarity of this method is that it allows to receive information without making any disturbance. The obtained spectra were used to determine the dust component's effect on the spectral characteristics of the buffer plasma.

Experiment

An experimental setup is based on a capacitive rf discharge and spatial spectrometer SDH-1 [9-10]. Schematic diagram of the experiment is shown below in Fig. 1 [10].

Plane-parallel electrodes are located in high-frequency (HF) chamber. The diameter of electrodes is 19 cm, distance between electrodes is 2 cm. The voltage applied to the lower electrode has a high frequency of 13.56 MHz. The upper electrode is grounded. The energy contribution to the RFCD under the experimental conditions is about 0.02 W • cm^{-3}. The pressure of argon gas varies in the range of 0,05-2 Torr. As dust particles polydisperse Al_2O_3 particles were used with average radiuses of 4 μm and 50 nm.

Investigation of optical properties of dusty RFCD plasma has been performed by recording the glow of argon discharge at the interval of 700-800 nm. Observation of plasma was carried out through the side window of the RF chamber. With the help of an optical system consisting of several lenses on the entrance slit of spectrometer SDH-1 a clear picture of the interelectrode space was produced. After the discharge is sparked dust particles had been dropped and formed the plasma-dust structures. Registration of the spectra was carried out using a digital camera, from which the information was retained in computer memory for further processing.

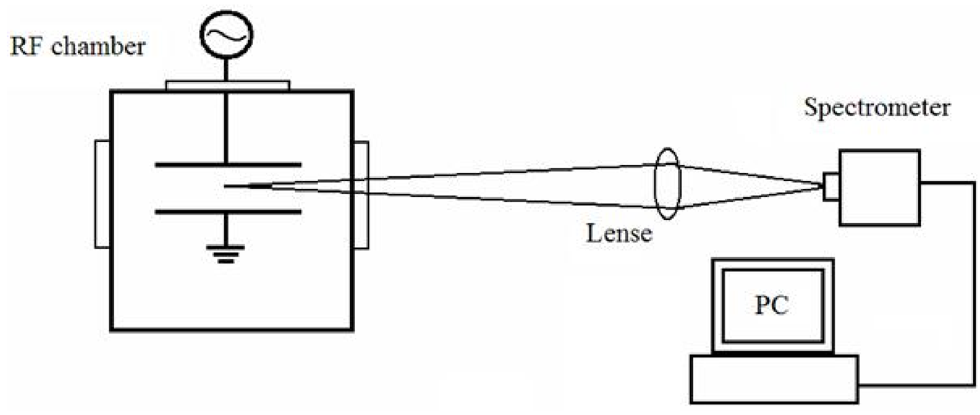

Fig.1. Schematic diagram of experimental RF setup for studying optical properties of plasma-dust structures.

Results

Typical spatial spectra of RFCD plasma in the range between 700 and 800 nm for pure argon at a gas pressure p = 0,2 Torr and discharge power P = 6 W are shown in Figure 2.

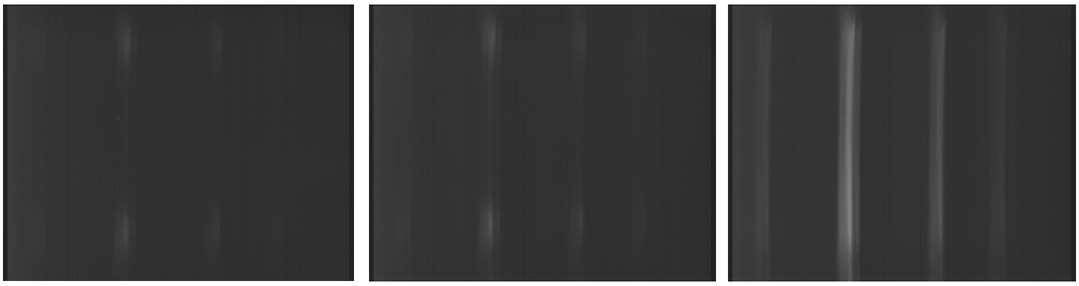

Fig.2. Images of the spatial spectra of RF discharge plasma at a pressure of working gas *p=0,2* Torr and discharge power *P=6* W. a) spectrum of a dusty plasma (with a lower concentration); b) spectrum of pure (bufer) plasma; c) spectrum of a dusty plasma (with higher concentration)

The upper part of spatial spectrum in the fig.2 corresponds to the luminescence near the upper electrode and the lower part corresponds to the luminescence near the lower electrode; the wavelength increases from the right side of the figure to the left side.

The characteristic functions of the light intensity spatial distribution in the area of 750.4 nm obtained for the discharge conditions corresponding to figures 2a, 2b and 2c are shown in Figure 3.

In the first case we took particles with radius r≈4μm and number density $n_d \approx 2 \cdot 10^2 cm^{-3} = n_1$, in the second experiment dust particles were absent and in third one they had high number density ($n_d \approx 10^5 cm^{-3} = n_2$, $r \approx 50\ nm$). The figure 3 shows the plots of the emission intensity at different values of dust particles number density and without them. Experiments with the number density n_1 showed weakening in the emission intensity in the near-electrode regions, whereas experiments with the number density n_2 demonstrated increasing in the intensity.

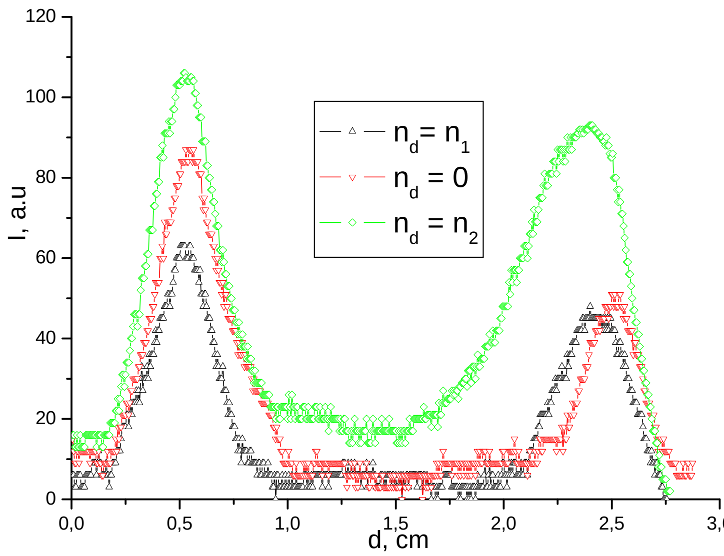

Figure 3. Spatial intensity distributions of the 750.38 nm argon spectral line in the absence and the presence of dust particles in plasma at the pressure p = 0.2 Torr and the discharge power Wp = 6 W

According to the obtained results one can see that the increase in of dusty particles density leads to increase in glow intensity. Concerning the dusty particles density we assume two effects: firstly, when dusty particles are introduced into plasma they trap fast electrons that is why plasma temperature decreases. Further increase in dusty particles density makes a barrier for the electron current. But the power should be retained constant, that is why self-discharge strives to increase the electric field, that leads to increase in the temperature, i.e. to increasing of glow intensity.

Conclusion

In this paper we performed experiments to study the optical properties of dusty plasma in a capacitive RF discharge of argon. Based on the study of RFCD plasma emission spatial spectra the dependence of the spatial intensity distribution of argon line of 750.4 nm was obtained. The influence of the dust component on the spatial distribution of spectral lines intensity has been identified.

The results of this study provide a basis for further investigation of optical properties of dusty plasmas. These results can be used to develop a methodology for contactless diagnostics not only of the buffer plasma, but also plasma-dust structures.

Acknowledgement

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