On the applicability of the Actinometry method in an nonuniform nonequilibrium gas-discharge plasma

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The actinometry method (method of the relative intensity of emission) is a widely used method for determining the concentration of particles in the plasma [1, 2]. It is implemented with the introduction of gas additive of small but known concentration (gas-actinometer) into the plasma gas and recording the emission spectra of both the analyzed particles and gas actinometer. For its application one needs to know the mechanisms of excitation of the analyzed particle and gas additive of known concentration. Also, one needs to be sure that the additive does not alter the properties of the plasma. The inert gases are commonly used as a gas-actinometer.

In recent years, the numerical modeling (2D) and experimental works have shown that in strongly inhomogeneous microwave discharge a small additive of argon leads to a change of the plasma parameters (electron density, intensity of the microwave field and the emission intensity of the plasma particles). This has been demonstrated for nitrogen [3] and hydrogen [4]. Modeling has allowed to show that the effect is observed if the transport coefficients of an ion of the additive differ from the transport coefficients of the main ion of the plasma.

The question arises whether this effect is observed in other types of the discharge? Here this problem is investigated by means of a one-dimensional model of a dc discharge in hydrogen. Argon is used as a small additive. Spatial nonuniformity in this work is determined by the shape of the electrodes. The two types of discharges are compared: a system with two symmetric planar electrodes and spherical electrodes - ball-sphere.

A self-consistent model in the local approximation [3] is used for the description of the discharge. The model includes the Poisson equation, Boltzmann equation for the free plasma electrons and kinetic equations for electrons, argon and hydrogen ions and the electronically excited states of argon and hydrogen. Simulation is carried out by means of the program Comsol 3.5a using the finite element method [5].

Simulations reveal a strong influence of small additives on properties of a dc discharge in a system with two spherical electrodes. Thus the actinometry method is not applicable in the case of strong spatial nonuniformity for any type of discharge.

The results indicate that the applicability of gas additives for plasma diagnostics must be analyzed in each case. On the other hand, they show that even small additions of inert gas can be used for controlling the parameters of the plasma.

References

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