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FORMATION OF AN INNER BOUNDARY LAYER IN THE CATHODE REGION OF A PLASMA PHOTOVOLTAIC CONVERTER *)

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The paper continues the development of the sodium vapor plasma model in the cathode region of the photoelectric converter, which began with the analysis of the temperature balance of heavy particles [1]. It was shown that the maximum temperature gradient of heavy particles is realized at some distance in the plasma depth. This causes a small value of the heat flux carried away to the cathode wall by the neutral component, which ensures high efficiency of direct photoelectric conversion. It is necessary to study the spatial distribution of electron temperature within the framework of a two-temperature plasma model to analyze the possibility of forming an internal boundary layer.

In this paper, the electron temperature balance for a three-component plasma in the region of partial local thermodynamic equilibrium (PLTE) is considered for a given distribution of the heavy particle temperature. The population of excited states of sodium atoms is assumed to be in equilibrium with a continuum with the corresponding values of temperature and electron density. The charged particle balance equation takes into account stepwise ionization, three-particle recombination, and associative ionization involving two resonantly excited sodium atoms Na(3P).

The electron temperature T_{eC}≈2800 K at the boundary of the ionization layer and the plasma PLTE was estimated using the condition of equality of the relative population of Na(3P) near the cathode wall and in the plasma depth in the region of local thermodynamic equilibrium. The rate of associative ionization exceeds the rate of stepwise ionization at the specified value of the electron temperature.

To form a stable internal boundary layer in the plasma, it is necessary that the electron temperature gradient takes a maximum value in the same region where the derivative of the spatial distribution of heavy particles reaches a maximum. Accordingly, the second derivative of the spatial distribution of the electron temperature should take a positive value near the cathode wall. When analyzing the heat conductivity equation for electrons, this is ensured by two conditions:

- the processes of electron cooling during elastic collisions with sodium atoms and ions should be predominant in the electron energy balance equation;

- a decrease in the thermal conductivity coefficient of the electron gas $\chi_e(T_e)$ with increasing electron temperature $\partial\chi_e/\partial T_e<0$ at $T_e \approx T_{eC}$. The non-monotonic behavior of the thermal conductivity coefficient of electrons is due to the fact that the radiative energy transfer is suppressed due to the high optical density of sodium vapor near the cathode wall. The electron thermal conductivity coefficient associated with the transfer of their kinetic energy can decrease with increasing electron temperature. This is realized in the case of predominance of associative ionization in the balance of charged particles, when an increase in the electron temperature leads to a decrease in the population of Na(3P) and a corresponding decrease in the ionization rate.

References

[1]. Gorbunov N.A. Proceeding of **L** International Zvenigorod Conference on Plasma Physics and Controlled Fusion, Moscow, 2023, Book of abstracts, p. 216.

*) abstracts of this report in Russian