Hybrid kinetic-liquid model of high-pressure gas discharge

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Abstract

As is known the direct solution of Boltzmann kinetic equation is of great interest for theoretical investigation of various gas discharges. Such approach gives the most important information about the discharge and its evolution by providing electron and ion distribution functions at given time point. The complete numerical solution of Boltzmann equations for multi-component gas discharge plasma is quite challenging even for one-dimensional problems due to high computational costs. That is the reason why gas discharges are usually described in terms of simplified moments models with drift-diffusion approximation or particle-in-cell (PIC) approaches with Monte-Carlo collisions. Main disadvantage of these techniques is that the description of fast particles (e.g. runaway electrons) is considerably difficult, especially for high pressures and strong overvoltages. For example, PIC method operates with restricted ensemble of macroparticles, so the accurate description of small portion of particles (like electrons with high energies) is simply unfeasible. Here we present the novel hybrid theoretical approach for the simulation of discharges in dense gases. Within its framework, both plasma hydrodynamics and kinetics methodologies are used in order to describe the dynamics of different components of low-temperature discharge plasma simultaneously. As a demonstration of current model advantages, we apply it to consider one-dimensional coaxial relativistic gas diode. Namely, in terms of our model it was shown that electrons power spectrum contains a group of electrons with the so-called "anomalous" energies (above the maximal applied voltage value) that were not correctly predicted before, but do exists it various experiments.

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