Active control of electron energy distribution function in dc discharge using an auxiliary electrode

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The plasma parameters of dc discharge with thermionic emission cathode and two anodes in helium are studied making use of two-dimensional PIC MCC simulations. The second anode is made as a diaphragm with a hole in the center. The discharge operates in two regimes depending on the radius of diaphragm hole and gas pressure. For smaller radius of hole and gas pressure an enhanced ionization occurs in the diaphragm hole. This results in formation of peaked profile of the potential and plasma density. The electron energy distribution function (EEDF) is nonmonotonic and exhibits a peak near ionization potential. Therefore, such EEDF can be effectively used for control of plasma chemistry and radical production.

All Earlier experimental studies [1,2] showed that the plasma parameters of dc discharge with thermionic emission cathode can be actively controlled by addition of the second anode made as a diaphragm with a hole in the center. This control is based on fundamental property of nonlocal electron kinetics [3] and can be beneficial for variety of applications. We simulated parameters of this dc discharge plasma making use of two-dimensional PIC MCC code. The schematic of the device is shown in Fig. 1. The geometry of device and plasma parameters are taken from Ref. [1]. The dc discharge operates in helium at gas pressure 0.5 – 4 Torr and is supported by the thermionic emission of electrons from cathode. The inter-electrode distance is 1.1 cm and the diaphragm is placed at distance 0.1 - 0.15 cm from anode. The discharge current ranges from 0.05A to 0.3A. The plasma characteristics, potential, electron and ion density profiles and EEDF are studied for different current densities, gas pressures and radius of diaphragm hole, and the distance between diaphragm and anode. The presence of the diaphragm leads to increased ionization only for a certain range of gas pressures and the radii of diaphragm hole. Outside this range, the enhanced ionization in diaphragm hole is not observed. The necessary conditions for operation of this regime are studied by varying gas pressure, current density and geometry of diaphragm hole.

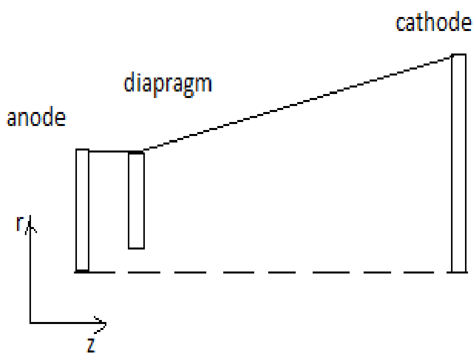

Fig. 1: Schematic of the device

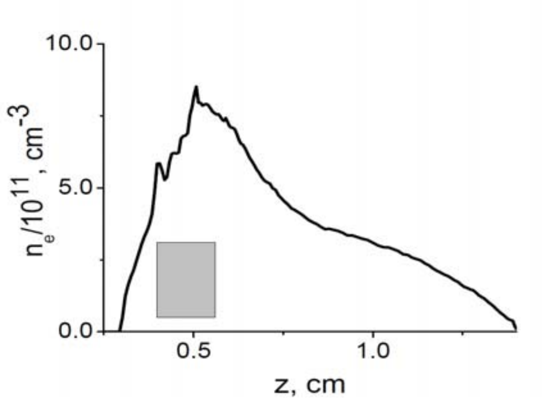

Fig. 2: Electron density profile along axis of symmetry. Grey box indicates location of the diaphragm.

Figures 2, 3 and 4 show typical plasma density and potential profiles, and EEDFs, respectively, for the discharge current of 0.1 A, gas pressure of 1 Torr and anode voltage of 30 V. The diaphragm radius is 0.15 cm. The electron density profile is peaked inside of the diaphragm hole, as shown in Fig.2. Figure 3 shows the double hump potential profile with potential drop of 7 V between diaphragm hole and cathode. In Figure 4, the electron energy distribution function is shown in the main plasma (z=1 cm) and inside of the hole (z=0.5 cm). The EEDF consists of several distinct groups. Group of fastest electrons originates from cathode (assumed at zero potential). These electrons have energy equal to the plasma potential in the hole (37 eV). Additional peak of the EEDF (17 eV) corresponds to electrons energy after inelastic collision.

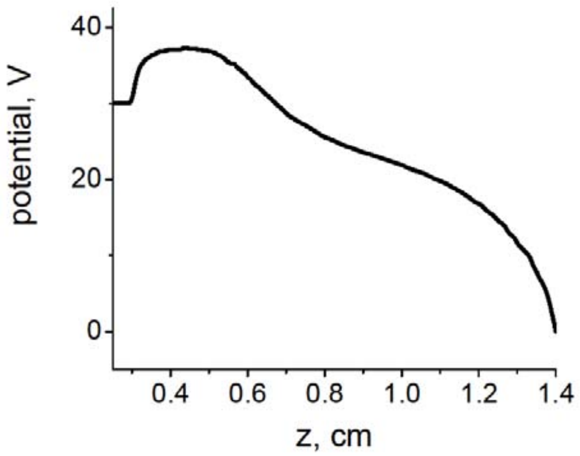

Fig. 3: Electrical potential distribution

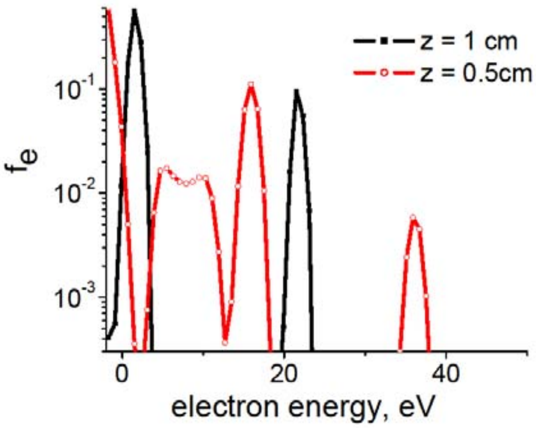

Fig.4: Electron energy distribution function on axis of symmetry at z=1 cm (bulk plasma) and z=0.5 (inside diaphragm hole)

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