Effect of electron secondary emission from the wall on sheath formation in dc discharge

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In gas discharge the sheaths form near the wall as well as near the electrodes to compensate the difference in mobility of light electrons and heavy ions. The potential drop near the wall extracts ions from the bulk plasma, accelerating them to the direction of the wall. The ion loss on the walls essentially decreases the plasma density. Additionally at low gas pressure and high density of plasma the sheath size is small and ions cross the sheath practically without collision. The high energy ion bombardment destroys the wall surface and reduces the lifetime of the devices. The wall potential is determined by balance of electron and ion fluxed coming on the wall. It is reasonable to assume that the dielectric wall with high secondary emission coefficient γ should have lower surface charge, and consequently, lower potential drop near the wall.

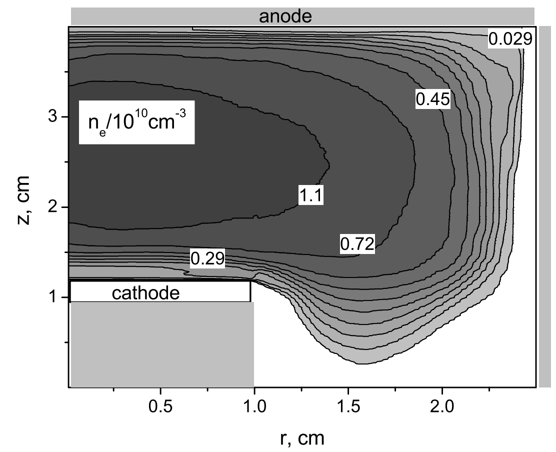

FIG. 1: Electron density distribution (measured in $10^{10}cm^{-3}$) for γ=0.54. z is the axis of cylindrical symmetry, dielectric wall is at r=2.5 cm.

Therefore, we perform PIC MCC simulations to study the influence of secondary electron emission (due to electron bombardment) on the sheath formation near the dielectric wall. We consider dc discharge with external magnetic field for the conditions of Hall thruster. The scheme of setup and calculation cell is shown in Fig.1.

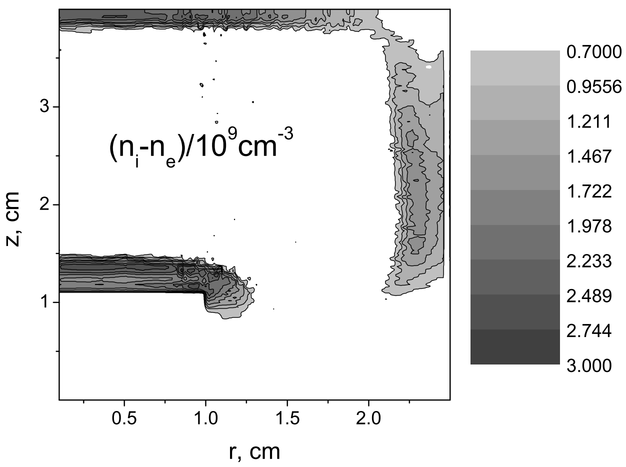

FIG. 2: Charge $(n_i - n_e)$ distribution (measured in 10^9cm^{-3}) for γ=0.54.

Dielectric wall has cylindrical shape with radius r=2.5 cm and z is the axis of symmetry. The radius of cathode is 1 cm. The inter-electrode distance is equal to 4 cm. The discharge glows in xenon at gas pressure P=10^{-4} Torr. The cathode voltage U is - 250 V and anode voltage is zero. The potential on the dielectric wall varies with z and is set by surface charge which is calculated. The bottom part the cylinder at $1cm < r < 2.5cm$ is open for electron and ion fluxes. The thermo-emission electron current from the hot cathode is j=30 mA/cm^2. The magnetic field profile has maximum of 60 G near the cathode and decays exponentially with the distance from cathode. In simulations we vary the secondary electron emission coefficient γ from the side dielectric wall from 0 to 0.85.

The discharge parameters are calculated with solving the system of equations, which includes the Boltzmann equations for electron and ion energy distribution functions, the Poisson equation for electrical potential, balance equation for the wall potential. The system of equations is solved self-consistently with PIC MCC method

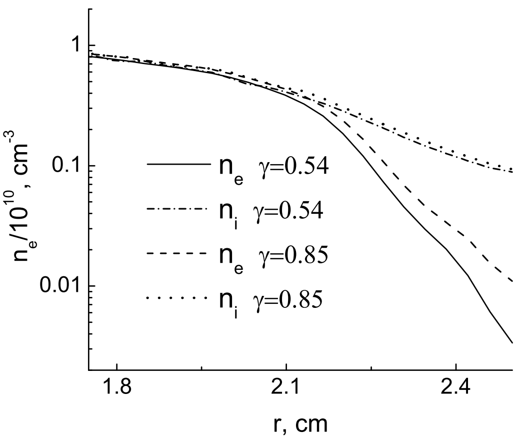

FIG. 3: Electron and ion distributions over r for z=2.2 cm for γ=0.54 and γ=0.85.

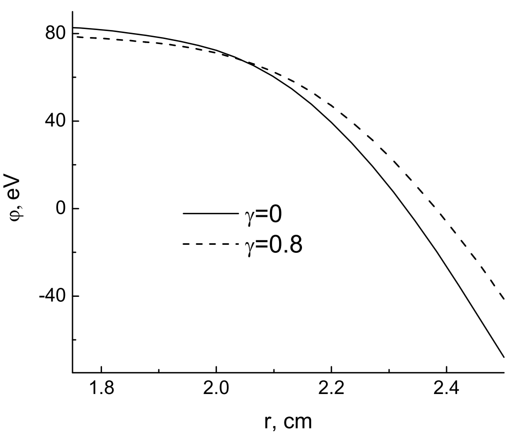

FIG. 4: Potential distribution over r for z=0.9 cm for γ=0; 0.54 and 0.85.

and the steady-state solution is obtained my iterative method.

In simulations the electrons emitted by the hot cathode surface cross the cathode sheath and gain energy. The cathode potential fall is about 300 V. The magnetic field applied in radial direction traps electrons, that provides sufficient ionization rate to support the discharge glow. Note that for smaller magnetic field the discharge plasma decays, since the ionization collision rate is small at this gas pressure. The charge distribution $(n_i - n_e)$ shown in Fig. 2 demonstrates the sheath presence near the wall and electrodes. It is seen that the sheath near the wall has extended structure. The radial distributions of electron and ion densities for the cases $\gamma = 0.54$ and $\gamma = 0.85$ are shown in Fig. 3 for z=2.2 cm. For the case of $\gamma = 0.85$ the electron density near the wall is high than for $\gamma = 0.85$, but the ion density remains almost the same for both cases.

The potential distribution in radial direction at z=1 cm for different γ is shown in Fig. 4. It is seen that the sheath width practically does not increases with decrease of γ, but the potential drop ϕ near the wall rises considerably. For example, ϕ=170 V for γ=0 and ϕ=116 V for γ=0.85.

In conclusion, in kinetic PIC MCC simulations we have studied the influence of secondary electron emission on the sheath formation near the wall in dc discharge with external magnetic field. It has been shown that for the case of dielectric materiel with higher secondary electron emission coefficient the potential drop near the wall becomes smaller, and, consequently, the ion loss on the wall decreases.