Space-charge sheaths on cathodes emitting neutral atoms

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The model of the space-charge sheath formed by cold ions and electrons at a negative surface has been established by Langmuir and Bohm. In the framework of this model, the ions enter the sheath from the quasi-neutral plasma, are accelerated by the sheath electric field and reach the surface without suffering collisions with neutral particles, the electrons are decelerated by the sheath field and are in equilibrium with it, i.e., follow the Boltzmann distribution. This model has been widely used for description of sheaths in low- and high-pressure gas discharges, as well as in vacuum arcs.

As far as the vacuum arcs are concerned, this model implies that the neutral atoms emitted from the cathode surface are ionized beyond the sheath and a part of the ions produced return to the cathode, thus forming the sheath. However, a comparison of δ the scale of thickness of the space-charge sheath with L the scale of distance which an atom emitted by the cathode travels before getting ionized shows that δ is not necessarily much smaller than L. This means that the ionization of emitted atoms may occur in the space-charge sheath rather than in the quasi-neutral plasma and the classic model may be unjustified.

As an alternative, one can think of the following model. The distribution of electrostatic potential in the sheath possesses a maximum. There is a maximum also in the distribution of the electric field, which means that the sheath is actually a double layer. There is a flux of atoms emitted by the cathode surface which are gradually getting ionized. The kinetic energy of the atoms is much smaller than the electron energy hence one can assume that the ions are generated at rest. The ions produced before the maximum of potential return to the cathode surface and those produced after the maximum escape into the plasma.

Apart from being of interest due to its relation to vacuum arc cathodes, the above-described model is of theoretical interest, in particular, due to its relation to the classic Tonks-Langmuir model of a collisionless column of a plane glow discharge. In this work, analytic and numerical solutions obtained in the framework of this model are given and discussed.

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