On universal properties of the plasma–sheath transition and large-size sheath structures

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Recently a unified Bohm criterion has been formulated [1] in the form of the ion directional energy expressed as a function of fluid, kinetic and electrostatic-pressure contributions. While the famous purely kinetic criterion of Harrison and Thompson [2], is satisfied exclusively at the plasma edge and for vanishing Debye lengths, the new unified Bohm criterion holds at any point of the discharge even if the quasineutrality is not well satisfied (i.e., in vicinity of the sheath entrance) irrespectively on the ion temperatures and Debye length, provided that the latter is small enough for the plasma criterion to be applicable. The plasma edge (PE) and the sheath edge (SE) have been identified as the points of inflection and the maximum of the charge density derivative with respect to the potential, respectively. Plasma quasineutrality is well satisfied up to the PE, with a non-negligible electrostatic pressure taking place only between the SE and the electrode/wall. The region between the PE and the SE, identified as the plasma–sheath transition (PST), turned out to be characterised by a universal value (about one third of the electron temperature) which is quite insensitive to ion temperature and the Debye length, while an increase in Debye length from zero to finite values causes the location of the sonic point/potential (lying inside the PST) to shift from the PE (for vanishing Debye length) towards the SE. Outside the PST, the electrostatic-pressure term and its derivatives turn out to be nearly identical with each other (independently of the particular values of the ion temperature and Debye length).

In the present investigation we investigate further the features described, however under the condition that the ionisation within the sheath, and thus the kinetic contribution to the unified Bohm criterion cannot be completely neglected. This is achieved by decreasing the plasma density, so that the sheath thickness is comparable with the plasma length, and with employing a constant ion production profile (independent of position, i.e., potential). The results obtained by means of the theoretical method from Ref. [1] are compared with the results obtained here after performing a series of kinetic numerical simulations. Special attention is paid to possible universal sheath solutions of large size, under the condition of a non-negligible ion production rate inside.

References

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