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2D model of hydrogen discharges with account for the volume produced negative ions

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The study is in the scope of the current two-dimensional (2D) modelling of gas discharges [1–3]. Hydrogen discharge maintenance in straight cylindrical gas-discharge tubes is treated. With the negative ions included in the model, the study is in the field of the research on volume-production based sources of negative hydrogen ions.

The model involves the balance equations of the charged particles (electrons, the three types of positive ions (H^+, H_2^+, H_3^+) and negative (H^-) ions) and of the neutral species (hydrogen atoms H and molecules $H_2(v = 1 - 14)$) excited to the fourteen vibrational states of the ground electronic states) and the electron energy balance equation, all of them solved with account for both time and space (radial (*r*) and axial (*z*)) dependences, as well as the Poisson equation. The production of the negative ions is via dissociative attachment of electrons to vibrationally excited molecules. The charged particle fluxes are drift-diffusion fluxes, with thermal diffusion of the electrons also taken into account. The rf power deposition to the discharge being radially homogeneous is shaped by a super-Gausian profile in the axial direction, centered at $z = 12.5$ cm.

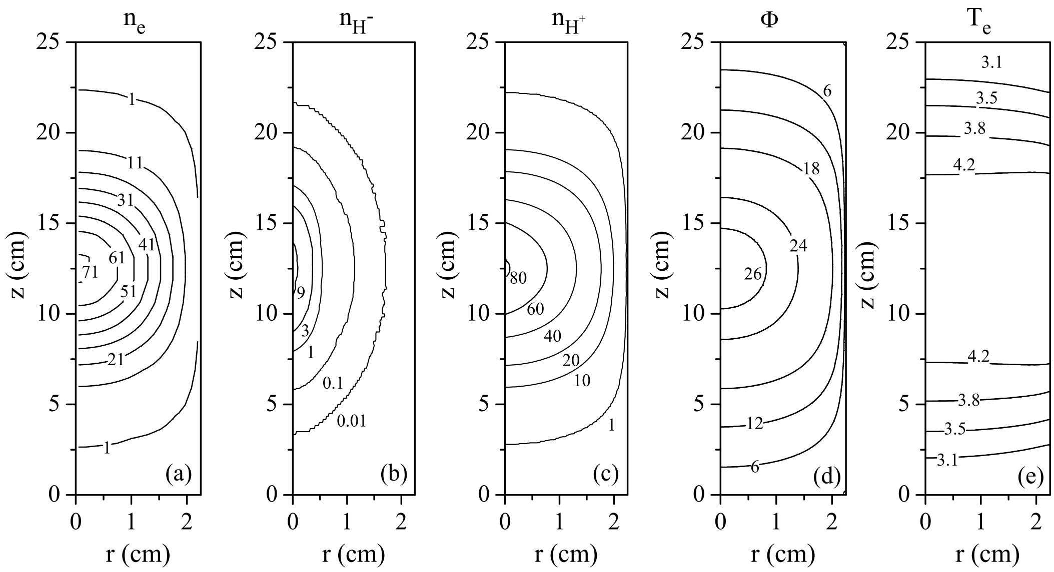

Fig. 1: Contour plots of constant n_e (a), n_{H^-} (b) and n_{H^+} (c) all in [10^{16} m^{-3}], Φ (d) in [V] and T_e (e) in [eV]. The figures show the modelling domain which is the half of the discharge vessel.

The fluxes at the walls (metal walls at a zero dc potential) and symmetry at the discharge axis $(r = 0)$ form the set of boundary conditions.

Figure 1 presents the 2D spatial distribution of the plasma parameters: densities n_e, n_{H^-} and n_{H^+} of electrons, of negative ions and of the dominating positive H^+–ions, as well as of the potential Φ of the dc electric field and of the electron temperature T_e. At the discharge center $(r = 0, z = 12.5\,\text{cm})$ n_e, n_{H^-}, n_{H^+} and Φ have maxima and decrease towards the walls both in the r- and z-directions (Figs. 1 and 2). Due to the dc electric field directed towards the discharge walls, the negative ions (Figs. 1(b) and 2) are strongly accumulated around the discharge center $(r = 0, z = 12.5\,\text{cm})$. This causes distortion in the spatial distribution of the positive ions (Figs. 1(c) and 2), with accumulation of positive ions there, for keeping the quasineutrality. The electron temperature, being slightly varying across the radius, decreases along the discharge length Fig. 1(e). In the central part of the discharge the electron density shows up with a Bessel-type of a radial profile (Fig. 2(a)).

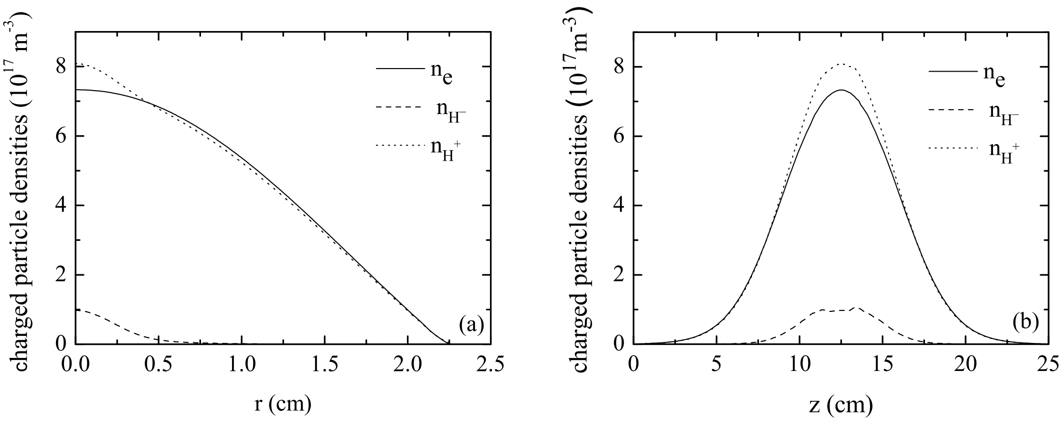

Fig. 2: Radial (r) and axial (z) variations of n_e, n_{H^+} and n_{H^-}, the former at $z = 12.5\,\text{cm}$ and the latter at $r = 0$.

The main conclusion is for a strong impact of the transport processes. The flux of the negative ions in the dc electric field is the reason for their accumulation in the discharge center. The latter, being in accordance with former results from a 1D model [4], influences strongly the whole discharge structure.

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Reference

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