EHD thruster discharge simulation on N_2-O_2 mixture at low pressure

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An axisymmetric 2D self-consistent electrohydrodynamic (EHD) thruster model is presented. In order to emulate air we considered a set of electron-impact reactions along with chemical and surface reactions for a total of 12 species and 26 reactions. The geometry of the thruster consists of a pin anode and a hollow funnel-like cathode to facilitate the flow of neutrals along the cathode interior. The ions tend to neutralize into their ground state upon contact with the electrodes and the simulation border. Additionally, when ions impact the cathode, a secondary electron emission occurs helping sustain the discharge. We found the concentration of each ion along the axis of symmetry to understand their role in the discharge.

1. Introduction and model

DC-discharges are typically studied with simple parallel plate-to-plate geometries which are not beneficial for thrust production. Our model presents a hollow cathode that allows charged particles to move between electrodes while neutrals flow inside the cathode chamber crossing it axially by momentum transfer collisions [1].

We solve the continuity equation for electron density and electron energy density, including source terms governed by the corresponding reaction rates of all the considered reactions.

The total considered species are: e, O, O_2, O_3, N_2^+, N_4^+, O_2^+, O_4^+, $O_2^+N_2$, O^- and O_2^-. For electron-impact reactions we use cross-section data. All reactions may be found on [2]. The pressure is 10 Torr (1333.2 Pa) and the voltage 400 V is applied through a RC circuit with R = 10 MΩ and C = 1 pF.

2. Results and analysis

The discharge was brought to convergence using a time-dependant solver using the finite-element software COMSOL Multiphysics® 5.2a.

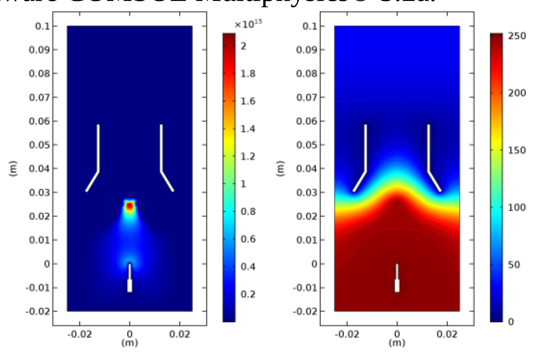

Figure 1: Spatial distribution of (left) electron density in m^{-3} and (right) electric potential in V. Pressure p=10 Torr.

In Figure 1 we can see the spatial distribution of the electron density showing a maximum value of 2.09×10^{15} m^{-3} at the entrance of the cathode chamber, which corresponds to the region where equipotential lines bend the most. The latter is due to the fact that electron cloud moves under the influence of the electric force, which is proportional to the potential gradient pointing to that region.

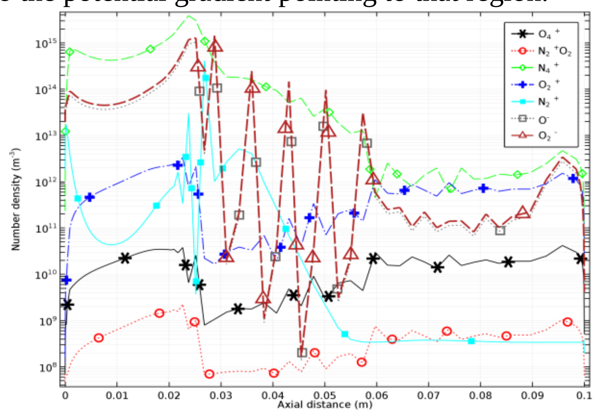

Figure 2: Number densities of all ions along the central axis. Pressure p=10 Torr, potential on anode V=250 V.

Ions number densities along the axial distance from the anode are shown in Figure 2; the N_4^+ specie is the dominant positive ion, followed by O_2^+ and N_2^+ since the momentum transmitted to the neutrals from Lorentzian collisions is proportional to the ions mobility, and considering the higher mobility of N_4^+ in dry air, its contribution is considerable in inducing gas flow velocity. The O_2^+ ion builds up in the region between electrodes reaching a density of 3.4×10^{12} m^{-3} and rapidly decreasing during the potential drop (2-4 cm along the line) and then presenting an increase becoming analogous to the N_4^+ ion outside the chamber.

3. References

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