Study of an Atmospheric Pressure Argon Microplasma Jet

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A surface wave discharge (SWD) in argon at atmospheric pressure generated by a Surfatron device, such as those used in the treatment of biomass for the production of bioethanol [1,2], is experimentally studied by optical emission and mass spectrometries. The measurements are complemented with the results from a self-consistent model of these discharges.

The electron density n_e, electron temperature T_e and gas temperature T_g were measured as a function of the applied power and gas flow rate. T_e was estimated using a collisional-radiative model that takes as input four emission lines originating from 4*p* states [1,3], while n_e was determined through the Stark broadening of the H_β line profile. The self-absorbing method was used to estimate the population of the metastable state $Ar(1s_5)$ [2,4]. The gas temperature was obtained from the rotational spectra of OH. The axial profile of n_e, from the launcher to the end of the plasma column, presents a maximum value under certain conditions, in contrast with the typical n_e profiles of SWDs, which are usually monotonically decreasing. A correlation between n_e and the metastable state $Ar(1s_5)$ was found, suggesting that stepwise ionization from metastable states may play an important role [1].

Employing mass-resolved ion-energy distribution measurements, it was possible to study the behavior of fourteen ionic species (Ar^+, Ar_2^+, ArH^+, H_2O^+, $H^+(H_2O)$, $H^+(H_2O)_2$, O^+, O_2^+, OH^+, NO^+, NO_2^+, N^+, N_2^+, N_4^+) of the plasma in diffuse and contracted modes [2]. The crucial role of three molecular ions (Ar_2^+, ArH^+, H_2O^+) during the radial contraction and the relationship between power, gas flow and molecular ions production is pointed out. Ion energy distributions for Ar_2^+, ArH^+ and H_2O^+ exhibit their maxima at high-energies, due to the low-energy threshold for three-body collision reactions.

A first modeling effort is done with the development of a self-consistent model of an SWD in Ar at atmospheric pressure. The model is based on the solution of the homogeneous electron Boltzmann equation, considering inelastic and superelastic collisions with the Ar(4*s*) states and electron-electron collisions, coupled with a system of rate balance equations describing the creation and destruction of the most important heavy particles, namely ground-state $Ar(^1S_0)$ atoms, the four Ar(4*s*) states, Ar(4*p*) states, treated here as a single effective level, the molecular dimmer Ar_2^*, as well as Ar^+ and Ar_2^+ ions. The simulations and experimental results are compared and discussed, providing physical insight into the basic mechanisms and phenomena ruling the discharge.

Acknowledgement: VG was partially supported by FCT (Pest-OE/SADG/LA0010/2013)

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