Air micro-plasmas generated by surface-waves in capillary tubes: spectroscopic diagnostics and kinetic modelling

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The research in micro-plasma sources has known a growing interest over the last years due to applications in several fields, such as photonics with the development of powerful UV sources, environment for the decontamination of organic material and biomedicine aiming the production of chemically active species, especially if the plasma is produced under controlled microfluidics flow conditions [1]. The use of microwaves is also an interesting choice, to achieve outstanding power transfer.

This work studies CW-microwave (2.45 GHz frequency) micro-plasmas, produced within a capillary (690 mm inner diameter) in dry air (N_2 80% : O_2 20%), at ~100 W coupled power and constant ~2 mbar pressure. The capillary is inserted into a surfatron, creating stable plasmas with ~3 cm length [2]. The plasmas are characterized using both diagnostics and modelling. State-of-the-art spatially-resolved (axially and radially) spectroscopic techniques are used to measure the line / band radiative emissions with H_β, $N_2(B)$, $N_2(C)$, N_2+, N* and O* to obtain the electron density n_e, the gas rotational temperature T_{rot} and vibrational temperature T_{vib}, and the absolute densities of the most relevant excited species. The measured quantities are used either as input parameters or for model validation.

Modelling uses a self-consistent hybrid approach that couples the homogeneous two-term electron Boltzmann equation to a set of 0D rate balance equations for the main neutral / charged species. A comprehensive kinetic scheme [3] is adopted in the model, considering the different collisional-radiative mechanisms with the complex atomic/molecular gas/plasma system and accounting for the evolution of the mixture composition due to the dissociation of species at constant pressure. The maintenance reduced electric field is calculated as eigenvalue solution to the problem, so as to satisfy the charged-particle gain-loss rate balance.

Results reveal a high-density non-equilibrium plasma, featuring $T_{\mathrm{rot}} \sim (700 – 1100) \pm 100$ K and $T_{\mathrm{vib}} \sim (50000 – 55000) \pm 1000$ K for $n_e \sim 10^{13}$ cm^{-3}. Discussion will analyse the production of species with these plasmas, considering the importance of the electron kinetics and focusing on the dissociation and ionisation degrees obtained.

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