MICROWAVE MICRO-PLASMAS AT ATMOSPHERIC PRESSURE

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This work presents three linear resonator sources, which use a continuous microwave (2.45 GHz frequency) excitation (1-50 W power) to produce stable micro-plasmas in air, helium and argon, at atmospheric pressure [1]-[2]. The discharges are produced and sustained within the 50-200 μm gap created between two metal electrodes (with 6 mm in length), placed at the open-end of a microstrip-like transmission line. For operation in a controlled gaseous atmosphere, the source is placed inside a chamber.

Particular attention is given to the design and optimization of the sources (in terms of frequency tuning and power coupling), following a complementary approach based on simulations (using the numerical tool CST Microwave Studio® and an analytical model of the transmission line) and experiments (spectroscopy measurements and an imaging analysis). Optical emission spectroscopy diagnostics allow deducing (i) the rotational temperature (T_{rot}) and the vibrational temperature (T_{vib}), using the N_2 (in air) and the OH (in Ar and He) rovibrational spectra; (ii) the excitation temperature (T_{exc}) and the electron density (n_e) in Ar, using atomic line transitions and the Stark broadening of H_β, respectively. Typically, we obtain T_{rot}~1000 K in air, ~600 K in Ar and ~400 K in He; T_{vib}~5000 K in air; T_{exc}~6000 K in Ar and ~4000 K in He; and n_e~10^{14} cm^{-3} in Ar. An imaging analysis is used to measure the plasma volume and to deduce its coupled power density (1-5 kW cm^{-3}).

Simulations involve also the self-consistent modelling of argon micro-plasmas, using a 1D self-consistent stationary hybrid code that solves the fluid-type transport equations for electrons, positive ions Ar^+ and Ar_2^+, and the electron mean energy; the rate balance equations for the main neutral species; Poisson's equation for the space-charge electrostatic field; Maxwell's equations for the electromagnetic excitation field; the gas energy balance equation for its temperature distribution; and the kinetic electron Boltzmann equation considering several direct and stepwise electron collisions processes. The model uses a kinetic scheme that considers the atomic excited states Ar(4s) and Ar(4p), two excimer states Ar_2* and Ar_2**, and two ionization states associated to the atomic and the molecular ions. Model predictions for the plasma power density and the gas temperature are in agreement with measurements.

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[1] J. Gregório, O. Leroy, P. Leprince, L. L. Alves, and C. Boisse-Laporte, IEEE Trans. Plasma Sci., **37**, 797 (2009).
[2] J. Gregório, L. L. Alves, O. Leroy, P. Leprince, and C. Boisse-Laporte, Eur. Phys. J. D, on line, 2010.