# Argon plasmas produced by a microwave (2.45 GHz) TIAGO torch as function of gas flow and microwave input power

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In the current work, argon microwave (2.45 GHz) flames produced by a microwave plasma torch called "*Torche à Injection Axiale sur Guide d'Ondes*" (TIAGO) in air entrainment at atmospheric pressure have been experimentally studied. Our results show the dependence of the shape of the flame and the spectroscopic parameters (gas temperature and electron density) on the feed flow rate whereas the dependency on input power can be neglected.

Atmospheric pressure microwave-induced plasmas (MIPs), specifically microwave plasmas torches, have been the object of an increased attention due to their potential and current use in several applications such as hydrogen production [1] or destruction of volatile organic compounds [2]. Among these torches, the "*Torche à Injection Axiale*" (TIA) [3] provides a very stable discharge that can operate over a wide range of experimental conditions (microwave power and gas flow). However, this device presents some problems, for instance, the vapor condensation in the metal channel through which the gas is supplied to create the plasma. In order to avoid them, an improvement of this torch, named "*Torche à Injection Axiale sur Guide d'Ondes*" (TIAGO), was developped by Moisan *et al.* [4].

TIAGO torch is a wave guide-based structure comprising waveguide and coaxial elements serving the purpose of wave-mode conversion and impedance-matching. Microwave power, from 100 to 1000 W, was provided by a SAIREM GMP KG/D microwave generator. Ar gas, with high purity (99.999%, Abelló Linde), was used as plasma gas which flew inside the rod until a conical nozzle where the flame appeared, with flows between 0.15 and 5.00 slm. In order to control the surrounding atmosphere of the flame a cylindrical glass reactor placed coaxially around the nozzle was designed.

In this research, the operating conditions of maximum stability of the discharge, as a function of flow rate and microwave input power, were studied. Besides, a description of the flame morphology with the gas flow is also presented. In order to obtain information about the microscopic and macroscopic behavior, gas temperature ($T_{gas}$) as well as electron density ($n_e$) have been studied by means of emission spectroscopy techniques; the radiation emitted by the flame was recorded by an optical fiber, placed at the end of the nozzle, and directed to the entrance of a Jobin-Yvon-Horiba monochromator (1000M, Czerny-Turner type).

In order to test the best energy coupling matching of the transmission line impedance with the plasma impedance the power reflection coefficient ($P_r/P_i$) as a function of input power ($P_i$) at different values of gas flow was obtained (Figure 1a); being $P_r$ the reflected power to the generator. As it can be seen from the graph (Figure 1a), when $P_i$ value ranges from 200 to 650 W the $P_r$ is less than 5% of the $P_i$; besides, in this power range, the coupling is independent on the gas flow used to generate the torch. These results show a wide range of powers and gas flows in which the TIAGO torch flames can be generated with a low reflected power coefficient.

The morphology of the plasma torch can be observed in Figure 1b. Two regions can be distinguished; a bright filamentary plasma column (dart) and a tenuous less intense broader region at the end of the dart (plume). For a given input power (Figure 1b), the plume tends to expand into the cylindrical glass reactor and reduces its size from flows higher than 1 slm. For these flows the dart length increases.

The gas temperature was measured from the ro-vibrational spectra of $N_2^+$ species [5] and its behavior with the experimental conditions can be observed in Figure 2a. One observes, for Ar flows higher than 1.50 slm, the gas temperature tends to maintain constant its value indepently on gas flow and microwave power. However, for flows less than 1.50 slm, the gas temperature presents different values and showing a tendency to decrease with the Ar flow.

Related to electron density (Figure 2b), it was obtained from the Stark broadening of the $H_\alpha$ spectral line. In Figure 2b, a continuous increase with the gas flow is observed up to flows of 1.50 slm,

$n_e$ tending to a saturation value from this flow. Besides, the influence of the input power can be considered negligible.

From these results, a relationship of the plasma parameters (gas temperature and electron density) and the flame morphology with the gas flow utilized as plasma gas is observed; the dependence on the input power is not as important as the gas flow.

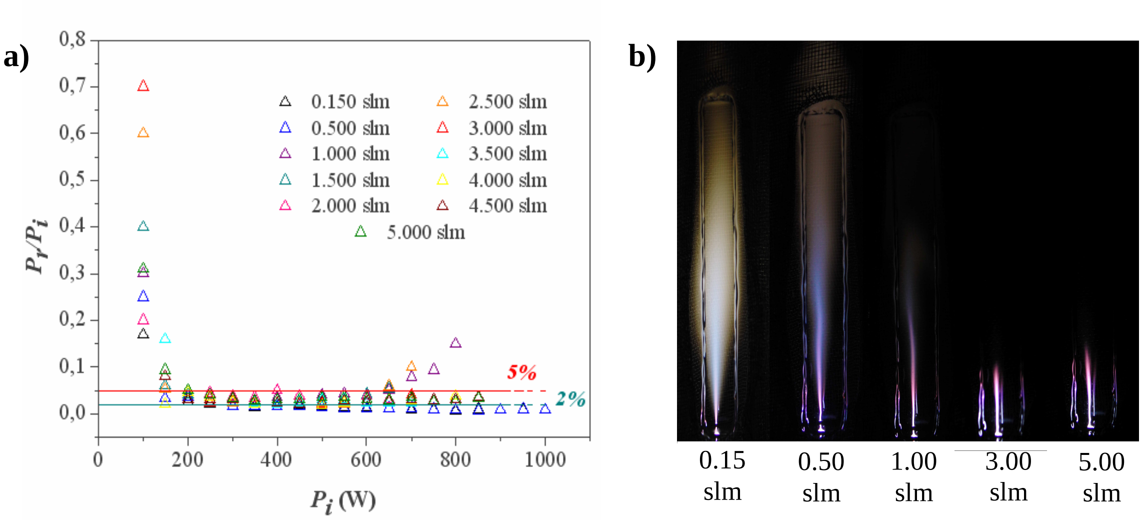


Fig. 1: a) Power reflection coefficient ($P_r/P_i$) as function of power and gas flow rate, b) several images taken (1/250 exposition time) from the flame generated at 450 W with Ar flows of 0.15, 0.50, 1.00, 3.00 and 5.00 slm.

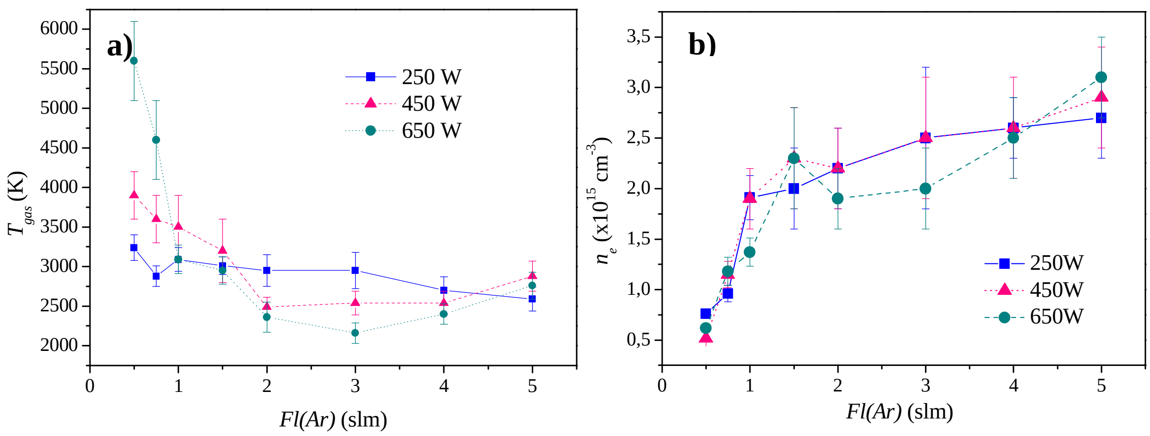


Fig. 2: a) Gas temperature obtained by means of the rotational temperature of $N_2^+$ specie and b) electron density calculated from Stark broadening of $H_\alpha$ line.

## References


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