Investigating the dynamics of a self-pulsing microscaled atmospheric pressure plasma jet

D. Schröder, S. Spiekermeier, S. Große-Kreul,
M. Böke, A. von Keudell, V. Schulz-von der Gathen*

Experimental Physics II, Research Department Plasma,
Ruhr-Universität Bochum, Bochum, Germany
**Contact e-mail:* svdg@ep2.rub.de

1. Introduction

Non-thermal, atmospheric pressure plasma sources possess an enormous potential for applications, e.g. in the manifold field of bio-medicine. An open challenge is to determine which species or which combination of species and radiation wavelength generated simultaneously is responsible for a specific biological response. Another one is how to generate an optimized mixture by controlling external plasma properties such as power, work gas selection or gas flow.

A second challenge, still demanding more fundamental research, is the requirement of stable and reproducible long-term operation of these plasma sources. This is contradicted by instabilities that are very often observed in microplasma discharges operated at atmospheric pressure. In the course of these instabilities, discharges transit from the stable homogeneous glow discharge to a spatially constricted discharge characterized by high light intensity. This phenomenon, so-called ‘arcing’, can result in a steep increase in gas temperature of the effluent.

2. The self-pulsing µAPPJ

Both challenges are addressed by the ‘self-pulsing’ µ-APPJ which is a further development of the well-known coplanar µ-APPJ [1]. It shows 1 mm wide and 30 mm long stainless steel electrodes with a wedged-shaped gap distance increasing linearly from 1 mm at the gas inlet to several millimeters at the nozzle.

One of the electrodes is grounded, the other one is capacitively driven at 13.56 MHz. Typically, helium at flows of about 1 slm with a small admixture of molecular oxygen (<0.6 vol%) is used [2]. Operated at sufficient power the device shows repetitive ignition, propagation and extinction of a constricted discharge between the electrodes with an underlying homogeneous α-glow.

3. Diagnostics

An understanding of this operation can be obtained by a combination of various optical, electrical and mass spectroscopic diagnostics. Phase-resolved optical emission spectroscopy (PROES) of nitrogen molecule and molecule ion emission bands reveal an increase of the rotational temperature within the constricted discharge to about 600 K within 50 µs inside the constricted discharge. Its propagation velocity was determined by phase-resolved imaging (PRI) to be similar to the gas velocity, in the order of 40 m s^{-1}. These results are combined with the phase-resolved analysis of high-resolution current and voltage measurements yielding phase and power [3]. As relevant species atomic oxygen (reactive species for biomedicine) and metastables (energy storage) have been investigated with synchronized two-photon absorption laser-induced fluorescence and tunable diode laser absorption spectroscopy, respectively. Both diagnostics reveal spatial regions of increased species densities co-propagating with the constricted discharge feature (Fig.1). Finally, time-resolved mass spectrometry is applied to investigate the evolution of ions within discharge and effluent.

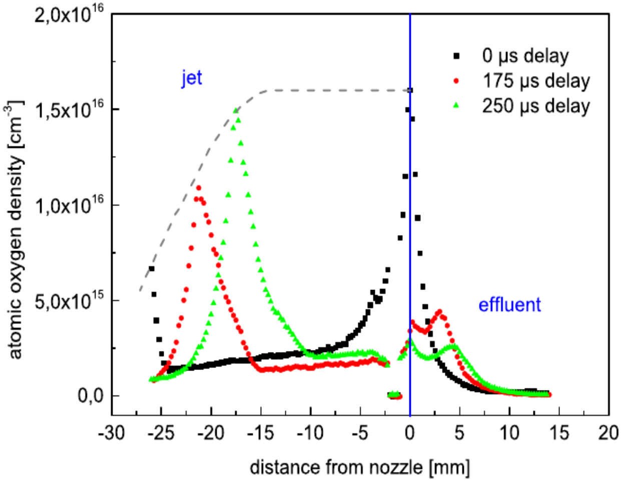

Fig. 1: Temporal evolution of the atomic oxygen density

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References

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