Flow characterization of the electro-thermal plume induced by nanosecond repetitively pulsed microplasmas

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The aim of this study is to describe the main characteristics of an electro-thermal plume produced by the interaction between a nanosecond repetitively pulsed microplasma generated between two tungsten electrodes and a DC biased metallic plate at a distance of 40 mm. The plume was studied by particle image velocimetry and Schlieren photography. The generated flow has a bi-planar topology and is characterized by both thermal and electrohydrodynamic flow. The impacts of the main parameters of the discharge are discussed, such as the pulse repetition frequency, plate distance and applied voltage. We will show how the properties at the micro-meter scale influence the generated flow.

1. Introduction

Non thermal plasmas generated in atmospheric air are useful in many research areas. Because of the complex composition of air, the selection of useful reactions and power management are difficult challenges. Furthermore, the presence of oxygen can cause strong heating and prevent the use of a more energetic and reactive discharge such as an arc or spark for certain applications. Nanosecond repetitively pulsed (NRP) discharges [1] can overcome these disadvantages by temporal control of the discharge regime and mean electron energy. These properties can be enhanced by adding surface interactions i.e. by confining the discharge to the micrometer scale. For materials applications, several configurations for the transport of reactive species from the plasma reactor to a substrate have been studied such as jets, sprays or just by placing the substrate in contact or near the discharge [2]. The aim of this study is to confine a NRP discharge to 200 µm in atmospheric air in a pin-to-pin configuration and investigate the impact of the presence of a DC biased electrode 40 mm away from the micro-plasma. The generated flow was analyzed by particle image velocimetry (PIV) and Schlieren photography.

2. Experimental setup

NRP micro-discharges were generated at atmospheric pressure in open air at room temperature between two tungsten electrodes sharpened to 280 µm radius of curvature and inclined at an angle of 45°. High voltage pulses, with 11-15 ns duration and up to 6 kV in amplitude were applied across this gap. For PIV, a laser was used to probe the flow at 16.25 kHz, with the beam shaped into a 1-mm thick laser sheet to illuminate seed particles.

3. Discussion

The presence of the plate with an applied potential of -14 kV or 14 kV placed near (i.e. at a distance of 5 to 40 mm from the microplasma) the microplasma generates an electrohydrodynamic flow. The velocity field in one dimension is presented in figure 1. The maximum flow velocity is not positioned along the central axis of the plume. We can identify the stagnation point on the plate along the center axis. The flow is not axisymmetric because the flow field is different in the perpendicular plane. After the presentation of some properties of the microplasma, the topology of the flow will be discussed further by presenting results with temporal resolution and better spatial resolution. The transport of the reactive plasma chemical species will also be discussed.

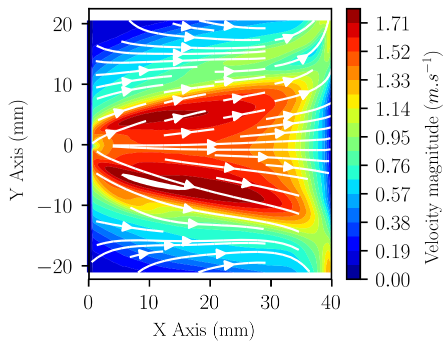

Fig. 1. Mean velocity field obtained over 6000 snapshots, the microplasma is placed at x = 0 mm and the plate at x = 40 mm

3. References

[1] D. Packan, Ph.D. thesis, Stanford University, 2003.

[2] D. Z. Pai, K. (Ken) Ostrikov, S. Kumar, D. A. Lacoste, I. Levchenko, and C. O. Laux, Sci. Rep. **3**, (2013).