Numerical study on the dynamics of He plasma jets with N_2 or O_2 admixtures

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Simulations performed with a 2D fluid model address the study of the dynamics of Helium plasma jets in dielectric tubes with several admixtures of N_2 or O_2 and different geometrical set-ups, applied voltage waveforms and repetition frequencies, to compare with several experimental conditions. Recently different techniques have been developed to measure the electric field in plasmas jets. In this work, comparisons are carried out between simulations on the electric field measured by an external electro-optic probe and measurements based on the Pockels effect. The influence of different gas mixtures and species kinetics on the jet post-discharge is also addressed. Finally, for repetitive conditions, the influence of initial conditions of species densities and surface charge deposition for the next jet is studied.

1. Introduction

Recently, to tailor the generation of reactive species in plasma jets for biomedical applications, several research groups [1-3] have studied the use of admixtures (mostly O_2 and N_2) to the helium buffer. Furthermore, there exists also a recent interest for the consideration of electric field associated with the plasma plume delivery over tissues, with the development of several different measurement techniques of the electric field [4-7].

In this work, we present a numerical study on the dynamics of a Helium plasma discharge with N_2 or O_2 admixtures in a dielectric tube. At the tube exit, the mixing of helium with air is neglected. However, to be close to experimental conditions a grounded target is set at 1 cm from the tube exit. In this work, we focus on the calculation of electric field and its comparison with experimental results in different conditions (geometry, applied voltage, repetition frequency) for both positive and negative polarities and for different gas mixtures.

2. Numerical model and results

The simulations are performed with a 2D fluid model. In order to study the influence of different amounts of N_2 and O_2 admixture on the helium discharge dynamics, detailed kinetic schemes have been used.

We first compare time-resolved measurements using an electro-optic probe [4] and simulations of longitudinal and radial electric field components, as well as the creation of species such as He*, associated with plasma propagation in the dielectric tube and in the plasma plume. A good agreement is obtained on the dynamics of both components of the electric field during the ionization front propagation in the tube. After the arrival of the ionization front at the grounded target, a rebound of electric field is observed for both positive and negative polarities of the applied voltage. Interestingly, a first increase of the density of He* is observed behind the ionization front and a second increase is observed due to the electric filed rebound. Then, a detailed study of the influence of the geometry of the set-up (electrode inside or outside the tube, location of the target) is presented.

Second, we compare simulations with the technique of measuring the electric field through charge deposition on a dielectric surface perpendicular to jet propagation [6].

Finally, as in most experimental conditions, sinusoidal or repetitive voltage pulses are used, we have studied the post-discharge of a jet for different gas mixtures. The dependence on the gas mixture of the initial conditions at the breakdown of each jet is also obtained for different repetition frequencies. Focus is given to the densities of species left in the gas inside the tube between discharges, as well as to the surface charges left in the tube inner walls.

3. References

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