Control of charged species dynamics in atmospheric pressure plasmas using tailored voltage waveforms

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Precise control of the chemical kinetics in atmospheric pressure plasma sources is crucial for their full potential to be realised in a range of applications. Radio-frequency plasmas driven by multiple driving frequencies offer an attractive route to achieve such control. In this work, we demonstrate wide-ranging control of charged species dynamics in He/N_2 plasma jets at atmospheric pressure using tailored voltage waveforms. Experimentally we employ using Phase Resolved Optical Emission Spectroscopy to measure the time and space resolved electron dynamics. Further insight into plasma control is obtained through comparison with one-dimensional fluid simulations.

1. Introduction

Atmospheric pressure plasma sources have been researched extensively for a wide variety of applications ranging from biomedicine to sustainable chemical feedstock production. For any application of these plasma sources to achieve its full potential control of both charged and neutral species dynamics is of key importance. However, only limited control is possible in plasma sources operated with a single fixed frequency. In low-pressure plasma sources, enhanced control has been demonstrated by employing multiple driving frequencies. In this work, we investigate multiple frequency operation for control of radio-frequency (rf) driven atmospheric pressure plasma sources using experimental measurements and numerical simulations.

2. Experiment and simulations

The plasma source used in this study has the same critical dimensions as the "COST Reference Microplasma Jet" [1]. The source is driven by tailored voltage waveforms (TVW) consisting of a fundamental frequency of 13.56 MHz with up to five harmonics. Both "pulse-type" and "sawtooth-type" waveforms are investigated. The plasma is formed in a feed gas of He with small N_2 admixtures. In order to observe the time and space resolved electron dynamics in the plasma we apply Phase Resolved Optical Emission Spectroscopy (PROES).

The experimental measurements are complemented by 1D fluid simulations using the model discussed in detail in [2, 3].

3. Results

Experimentally, it is observed that the time and space resolved electron dynamics are strongly dependent on the number of harmonics constituting the driving voltage waveform. Significant differences are also observed in the electron dynamics in plasmas driven by "pulse-type" and "sawtooth-type" waveforms.

Simulations carried out under the same operating conditions demonstrate that this control of the time and space resolved electron dynamics results in control over the time and space averaged electron energy distribution function (EEDF). The simulations further show that this allows for control over the densities of both charged and neutral species in the plasma.

The wide range of control possible using this technique offers significant potential to tailor plasma properties in different gas mixtures for specific applications, which will be of importance for future applications of atmospheric pressure plasmas in industry and biomedicine.

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