Gas flow modifications by a kHz microsecond atmospheric pressure plasma jet

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In this work we present Schlieren images of a Plasma Gun discharge fed with several helium buffer admixtures (pure, O_2, N_2). It has been demonstrated that efficient gas flow channelling is observed with pure helium. Such gas flow channelling is also proven to be dependent on voltage polarity and frequency. Analysis of the role of molecular admixtures (N_2 or O_2) confirms the non-thermal nature of the effect and the potential crucial role of large negative ions. In order to get a better understanding of this effect, numerical simulations have been carried out to study the dynamics of formation of positive and negative ions in helium with various amounts of N_2 or O_2 admixtures. The influence of mixing the gases in the buffer or downstream is also studied.

1. Introduction

Atmospheric pressure plasma jets are effective for biomedical applications thanks to several factors but mainly due to reactive oxygen and nitrogen species (RONS). Yet, it has been shown that plasma jets change the gas flow, influencing RONS production and delivery. Several parameters have already been investigated with pure helium fed plasma such as pulse frequency, gas flowrate and voltage polarity [1]. Even though it sounds tempting to add O_2 or N_2 to enhance RONS' production, no study shows how it modifies the gas flow.

In this study we present Schlieren images of a Plasma Gun (PG) discharge fed with pure helium and then with admixture of O_2 and N_2. Gases were mixed in two different places: before and after the reactor. The collected images were compared to numerical simulation results of plasma jet propagation in conditions as close as possible to experiments.

2. Experimental Setup and modelling

PG is powered by µs duration voltage pulses. A conductive grounded metallic plate is placed 2 cm away from the glass capillary outlet in order to mimic PG operation for biomedical applications. A classic Z-Schlieren is used to reveal rare gas density gradients in ambient air. The simulations are performed with a 2D fluid model for plasma propagation with several He-N_2 and He-O_2 gas mixtures using detailed kinetic schemes [2,3].

3. Results

In pure helium, the gas flow structure was mainly controlled by voltage polarity and pulse frequency. There exists a limitation in frequency depending on gas flow, for example 500 Hz at 0,5l/min, below which it is impossible to channel the gas. With positive polarity, gas flow was disturbed above the target while with negative one, a well-defined channel was created. This behaviour has also been observed with neon and argon. Then Schlieren revealed that adding a small amount of O_2 was enough to deeply modify gas behaviour. It helped channelling the gas to the target in a well-defined way, even in positive polarity. In negative polarity both effects (polarity and addition of O_2) were working together, as an even smaller amount of O_2 was enough to channel the gas. Moreover, the more O_2 was added, the lower was the limitation of frequency. Hence a 100Hz-powered plasma managed to channel the gas thanks to a 2%-O_2 addition. It has to be noted that if mixing helium and O_2 in negative polarity is very effective, a too large amount of O_2 prevents plasma ignition. Nevertheless no difference with pure helium was observed when N_2 was mixed with helium. When O_2 was added downstream the reactor, the same behaviours have been observed even if the channelling was more effective with a mixture added upstream. The simulation results show the formation of positive and negative ions in several He-N_2 and He-O_2 gas mixtures, adding the admixtures in the buffer or downstream.

4. Acknowledgments

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5. References

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