Plasma-liquid droplets interactions in a surface-wave plasma column at low pressure

V. Orlandi[1,2,3], J. Brochier[1,3], M. Dion[1,3], A. Paillet[2], M. L. Kahn[3], L. Stafford[4], R. Clergereaux[1]
[1]*Laboratoire Plasma et Conversion d'Energie, Laplace, Université Paul Sabatier, Toulouse,*
[2]*France Spaceship FR, CNES, Toulouse, France*
[3]*Laboratoire de Chimie de Coordination, LCC, CNRS, Toulouse, France*
[4]*Département de Physique, Université de Montréal, Montréal, Québec, Canada*

Abstract: Aerosol injection in a plasma via liquid spraying is an alternative to classical plasma deposition methods. However, the impacts of droplets on the plasma behavior is a complex problem. In this contribution, the response of a surface-wave plasma to pulsed aerosol injections is investigated. For a given injected power, the plasma cannot be further sustained when increasing the droplet number due to electron losses on the liquid droplets.

1. Introduction

Aerosol injection into a plasma is an interesting method to form innovative coatings [1]. However, plasma-droplets interactions can highly affect the process. Pulsed aerosol injection allows for better control by re-establishing equilibrium between pulses. However, as discussed in dusty plasma, the interactions between plasma and droplets are complex with really different time scales [2]. This study focuses on the behaviour of surface-wave plasma at low-pressure under pulsed gas injections. Depending on the pulse injection time, one must increase the power injection to sustain the discharge. This can be attributed to electron attachment on liquid droplets during their transport in the plasma column. In addition, droplets are modified in contact with the plasma, causing partial vaporization. A key role of the droplet number is observed.

2. Methods

The plasma reactor consists of a dielectric tube with a diameter of 30 mm and a length of 1 m. The surface-wave plasma is sustained by an electromagnetic wave generated by a high-frequency generator operating at 915 MHz, which is directed toward the plasma using a Surfatron wave launcher placed in the centre of the tube. An injection system operating in a pulsed mode is connected to the upper limit of the dielectric tube, so that the aerosol is sprayed downstream directly into the plasma. Liquid droplets of pentane are injected in a continuous flow of argon, at a flow rate set at 33 sccm corresponding to a working pressure of 1 mTorr.

3. Results and Discussion

Upon injection of aerosol in the plasma, different kind of instabilities can be observed. The most remarkable phenomenon is the abrupt extinction of the plasma, that can occur at the passage of aerosol during pulsed injections. This behaviour appears over a large range of power (up to 100 W) and for injection times higher than 5 ms (for an injection frequency in the 0.1 to 1 Hz range). In addition, it is observed at lower power for lower injection times. To emphasize the power – injection time dependence, Fig. 1 reports an operating domain.

Considering that the plasma column is maintained by a gain/loss equilibrium of the charged species, it suggests that droplets introduce a new loss term. It can be attributed to the charging of the liquid droplets related to electron attachment thus preventing the sustaining of the discharge [3]. For longer spraying times, a higher number of droplets are injected in the plasma (from 2×10^9 droplets for 3 ms to 5×10^9 droplets for 10 ms), thus increasing the electron losses. These effects are also observed by rapid camera, interferometry, and optical emission spectroscopy.

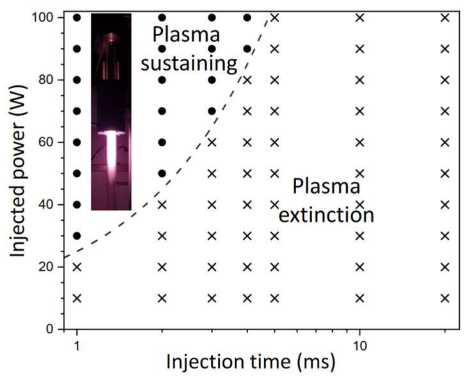

Fig. 1 Operating diagram of a surface-wave plasma with pulsed pentane injections.

Moreover, traveling in the plasma column, the liquid droplets are modified. Essentially, the plasma-droplet interactions induce liquid evaporation reducing the droplets average size.

4. Conclusion

As a conclusion, the behaviour of the plasma is strongly influenced by its interactions with liquid droplets, as discussed in misty plasma. This dynamic system is complex, involving both plasma-droplet interactions and plasma alteration with the aerosol flow.

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