Ionic composition of the spatial afterglow of an atmospheric pressure He/CO_2 plasma jet by mass spectrometry

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In this contribution, we report on the first measurements of the dominant positive ions in the effluent of a helium atmospheric pressure plasma jet (APPJ) discharge with CO_2 addition. The plasma is ignited in a He-CO_2 gas mixture with CO_2 flows from 0.1 – 0.5 %. The measurement of the positive ions in the effluent of the jet, at distances from 1 mm to 5 mm is performed using an energy resolved mass spectrometer with 2 pumping stages. It is found that at 1 mm distance the dominant ions in the effluent are $\mathbf{O_2^+}$ ions, and the $C_xO_y^+$ related observed ions are CO_2^+, $C_2O_2^+$, $(CO_2)O_2^+$ and $(CO_2)_2^+$ ions. The key finding is that the most abundant ions are $\mathbf{C_2O_2^+}$, $\mathbf{(CO_2)O_2^+}$. Due to presence of residual water in the system, many clustered ions have been observed as well, such as $(H_2O)_2H^+$, $(H_2O)O_2^+$, $(CO_2)(H_2O)H^+$ and $(CO_2)_2(H_2O)O^+$.

1. Introduction

CO_2 plasma gas conversion carries the promise of both energy storage and the reduction of a greenhouse gas emission produced by industrial processes and power plants. Both for the accurate description of the plasma dynamics via modelling or through plasma diagnostics, it is necessary to have an accurate description of electron kinetics. In that respect, it is necessary to know the ionic composition which will govern recombination rates.

In this contribution, we investigate the positive ions composition in the effluent of an APPJ jet [1] in He+CO_2 gas mixture using energy resolved ion mass spectrometry. The μ-APPJ comprises two RF powered (13.56 MHz) metallic electrodes separated by a 1 mm wide gap. The plasma is ignited between the electrodes in a gas mixture of interest.

Mass spectrometry of atmospheric pressure plasmas has been used for sampling of stable neutral and ion species by using differentially pumped multiple stages [2]. Mass spectrometry has the advantage of measuring the absolute densities of neutral species, but with limitation on measuring them only in the plasma effluent. Using a molecular beam mass spectrometer for neutral species, the neutral species composition of the APPJ in He+CO_2 gas mixture was measured and conversion rates are obtained.

2. Results

The measurement of positive ions in the effluent of the jet, at distances from 1 mm to 5 mm is performed using an energy resolved ion mass spectrometer. The ion signal intensities is optimized for each ion mass and correlated to the area of the energy resolved ionic distribution function.

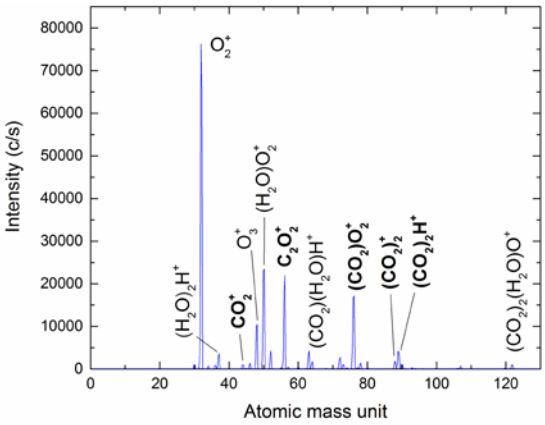

Figure 1. Mass spectrum with 0.1% CO_2/He gas flow ratio and measured at 1 mm from the outlet.

The first observation is that Helium ions are not observed. This is due to their efficient charge transfer reactions will all molecular species present in the discharge and its effluent. It is found that at 1 mm distance the dominant ions in the effluent are O_2^+ ions, and the $C_xO_y^+$ ions. Due to presence residual water in the system, many water based ion clusters have been observed additionally. Increasing the distance and increasing the CO_2 flow result in the reduction of the $C_xO_y^+$ ions (probably due to a decrease of the electron density) and dominance of $C_xH_yO_z^+$ related ion clusters.

3. References

[1] von der Gathen V S, Schaper L, Knake N, Reuter S, Niemi K, Gans T and Winter J 2008 *Journal of Physics D: Applied Physics* **41** 194004

[2] Benedikt J, Hecimovic A, Ellerweg D and von Keudell A 2012 *Journal of Physics D: Applied Physics* **45** 403001.