28th Summer School and International Symposium on the Physics of Ionized Gases

Aug. 29 - Sep. 2, 2016, Belgrade, Serbia

CONTRIBUTED PAPERS

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ABSTRACTS OF INVITED LECTURES, TOPICAL INVITED LECTURES, PROGRESS REPORTS AND WORKSHOP LECTURES

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University of Belgrade, Faculty of Physics

Serbian Academy of Sciences and Arts

CHARACTERIZATION OF AN ATMOSPHERIC PRESSURE PULSED MICROJET

M. Vinic[1], B. Stankov[1], M. Ivkovic[1] and N. Konjevic[2]

[1]*Institute of Physics, University of Belgrade, Belgrade, Serbia*
[2]*Faculty of Physics, University of Belgrade, Belgrade, Serbia*

Abstract. The results of an experimental study of atmospheric pressure pulsed microjets in helium and gas mixture are presented. The images of plasma jet propagation were recorded and emission spectra from glass discharge tube and plasma jet were analyzed and compared. From helium spectral lines electron density was calculated for several different configurations of discharge source. Temporal dependence of electron density was determined. The influence of various capacitors and discharge voltages on plasma jet emission and propagation were studied also.

1. INTRODUCTION

Atmospheric pressure He microdischarges have many different configuration and many applications. Most of them are constructed in order to obtain cold plasmas for medical and plasma chemical applications. It can be used for cleaning, decontamination, etching, or coating surfaces at atmospheric pressure and low temperature. [1] One reason for why plasma jets are advantageous is because even though the electrons are hot, the overall gas is at room temperature. Another important advantage of using atmospheric plasmas is the possibility to process materials which are not resistant to vacuum. [2,3] The main disadvantage of such microdischarges is high consumption of He.

Here, we present attempt to construct and characterize low flow atmospheric pressure He single pulse plasma microjet.

2. EXPERIMENT

Schematic sketch of pulsed atmospheric pressure plasma jet is shown in Figure 1a. The experimental setup consists of microjet, focusing optic, radiation intensity detection system (imaging spectrometer equipped with ICCD camera), computer and electronics system for synchronization, detector gating and spectrum storage, Figure 1b:

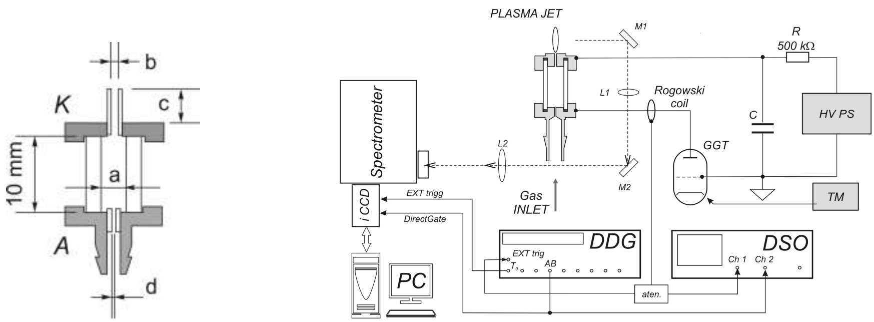

Figure 1. a) Microjet; b) Experimental setup.

Light emitted from microjet was focused by the use of lens L_1 having focal length of 32 cm. For the recordings of plasma jet images an additional lens L_2 was used having focal length of 17 cm.

Plasma image was projected on the 20 µm wide entrance slit of the 0.3 m imaging spectrometer Andor Shamrock 303, equipped with ICCD camera. The camera gating was performed with digital delay generator (DDG) by processing signal from Rogowsky coil which was used for current pulse measurements. The spectra were recorded at different delay times in respect to beginning of current pulse monitored by digital storage oscilloscope (DSO). The fast pulse discharge is driven by a different capacitors - C, charged with high voltage power supply - HV PS.

In microjet gas is fed through a hole in center of lower electrode (d), with passage trough glass tube and output through hole in an upper electrode (b) see Fig. 1a. Glass tubes with various inner diameters were used (a). In some cases, stainless steel tubes (SST) of different lengths were placed in upper hole (c), Table 1.

Table 1. List of different configurations of microjet.

label	MJ1	MJ2	MJ3	MJ4	MJ5	MJ6	MJ7	MJ8	MJ9	MJ10	MJ11	MJ12
a [mm]	4	4	4	4	4	4	2	2	1	1	1	2
b [mm]	0.50	0.70	0.70	0.70	0.70	0.45	0.70	0.45	0.70	0.70	0.45	0.5
c [mm]	0	6	15	0	6	6	6	6	0	6	6	0
d [mm]	0.50	0.10	0.10	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35

First step of our experiment was to record plasma images. After analyzing images, next step was to record spectrum of main discharge and plasma jet area. Helium and gas mixture (He with 1.5% CO_2 and 1.5% N_2) were used as carrier gasses. For the electron density determination we used the separation between allow and forbidden component of He I 447.1 nm line [4].

3. RESULTS AND DISCUSION

Due to an insufficient space in this publication we show only several results out of large number of images and spectra recordings.

Images of jet propagation were recorded, see example in Figure 2. First image depicts emission from discharge tube and plasma jet. In order to record images of jet, emission from discharge tube was blocked. It was discovered that jet appears 1 μs after beginning of discharge current, reaches maximum intensity at 2.5 μs and lasts until 14 μs. Based on these observations time and spatial position of subsequent measurements were selected. Another result from images appeared - in this type of discharge there is no plasma propagation, i.e. plasma stays in contact with upper electrode.

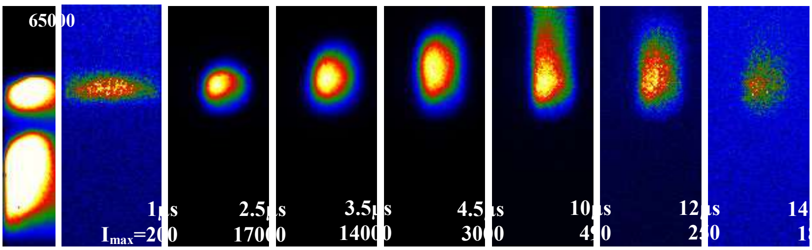

Figure 2. Images of jet evolvement. Each image is normalized to max light intensity.

In order to obtain aperiodic waveform of discharge current the resistor (0.4 Ω) connected in series with discharge was used. Figure 3 illustrates different current waveforms depending on used capacitor and applied voltage:

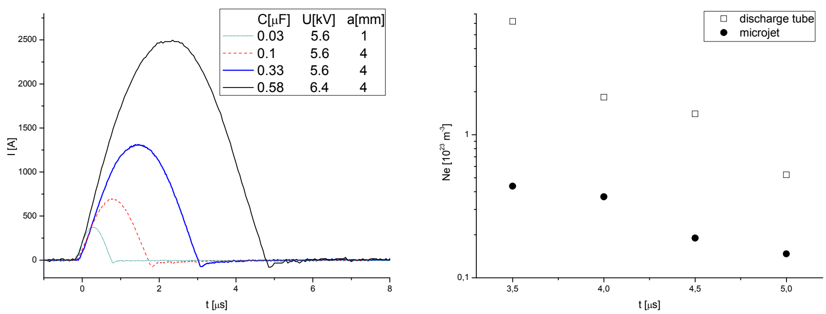

Figure 3. a) Current waveform depending of C and U; b) Temporal dependence of electron density for discharge tube and microjet (MJ12), C=0.33 μF, U=3.6 kV.

Temporal dependence of Ne for microjet without SST is shown in Figure 3b. Strong continuum obstructed estimation of Ne at the beginning of discharge so first evaluated Ne value is at 3.5 μs. At that moment, electron density in discharge tube is $6.2\cdot10^{23}$ m^{-3}, while Ne in jet is $4.4\cdot10^{22}$ m^{-3}.

The distinction between spectra from discharge tube and jet is shown in Figure 4a.

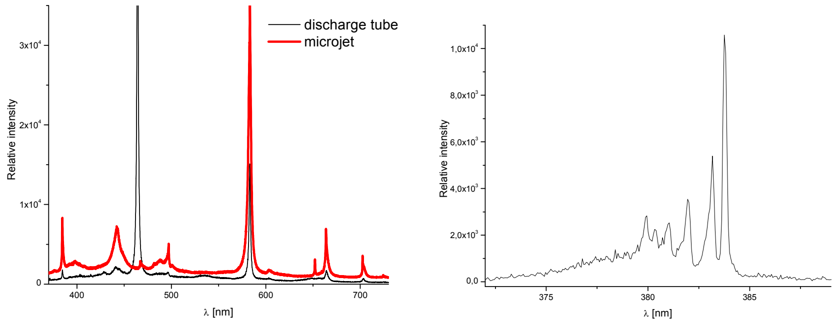

Figure 4. a) Comparison of spectra from discharge tube and microjet (MJ1), C=0.33 μF, U=5.6 kV; b) N_2^+ FNS (MJ8), C=0.33 μF, U= 5.6 kV.

Molecular bands of N_2 were detected in spectra when gas mixture was used as carrier gas, see Figure 4b. This is an indication that plasma jet temperature is low.

Acknowledgements

This work was financed by the Ministry of Education, Science and Technological Development of the Republic of Serbia under Project OI 171014 and TR 37019.

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