Microdischarge in the Vortex Gas Flow

Chernyak V., Solomenko Ok., Solomenko Ol., Lendiel V., Kalustova D., Prysiazhnevych I.

Taras Shevchenko National University of Kyiv, Glushkova av. 4g, Ukraine, chernyak_v@ukr.net

Current-voltage characteristics of the DC microdischarge were investigated in the work. The plasma jet parameters ware evaluated by emission spectroscopy method. The component composition and the temperatures of excited electronic, vibrational and rotational levels of plasma component of microplasma were determined by using emission spectra. It was found that nitrogen was the main component of microdischarge plasma. Also NO and OH molecular bands were presented in the spectrum.

Keywords: atmospheric pressure plasma, microdischarge, plasma jet

1 INTRODUCTION

Today, the development of atmospheric pressure microplasma jet is highly promising and perspective, because such plasma system is a source of low temperature atmospheric pressure non-equilibrium plasmas. Numerous plasma components such as activated components of oxygen or nitrogen, charged particles, electric fields and even UV radiation leads to different reactions in the treated tissues, allowing to use of microdischarge systems for various applications. The main advantages of these systems are their compactness, and the fact that the plasma is not limited by the sizes of electrodes. The ability to adjust the size of the plasma jet allows to locate the area of microplasma jet influence. It is important in the case of working with living tissues, in blood coagulation, in dentistry, in treating patients with diabetes, the plasma sterilization of living tissues etc. Conversely, it is also possible to increase the area of plasma in cases where it is necessary.

Commonly used discharges for the generation of atmospheric pressure plasmas are barrier discharge, corona discharge and microdischarge. The last one is similar to the glow discharge at low pressure. The microdischarge is the least studied among those discharges.

This research studies the properties of atmospheric pressure DC microdischarges in the air vortex flow. The electrical parameters of the discharge and optical characteristics of the microdischarge plasma jet have been studied.

2 EXPERIMENTAL SETUP

The Fig.1 shows a schematic representation of atmospheric pressure microdischarge plasma generator, which has axially symmetric design with geometry similar to the known HF systems [1]. The internal high-voltage electrode (rod) has a rounded end. Its diameter is 1 mm. The role of the second external grounded electrode is performed the body of this design. The outlet aperture diameter (d) was $0.5 \div 2.0$ mm. The space between the electrodes was blown over by the vortex flow of working gas. Air was used as working gase.

The working gas is introduced tangentially to the side wall of the cylinder, thus forming a reverse vortex flow. Plasma jet rotates under the influence of the gas flow, gliding over the surface of the upper electrode. The design provided an additional channel of gas supply to the reaction chamber. The system can work both horizontally and vertically.

The main advantage of the method of emission spectroscopy is the ability to investigate plasma parameters without interfering in plasma itself. Plasma emission spectroscopy usage allows to determine the composition of the plasma, the temperatures population of excited electronic levels and determining the vibrational and rotational temperatures of atomic and molecular plasma components. This is why this method is used for the research of plasma microplasma jet system described above.

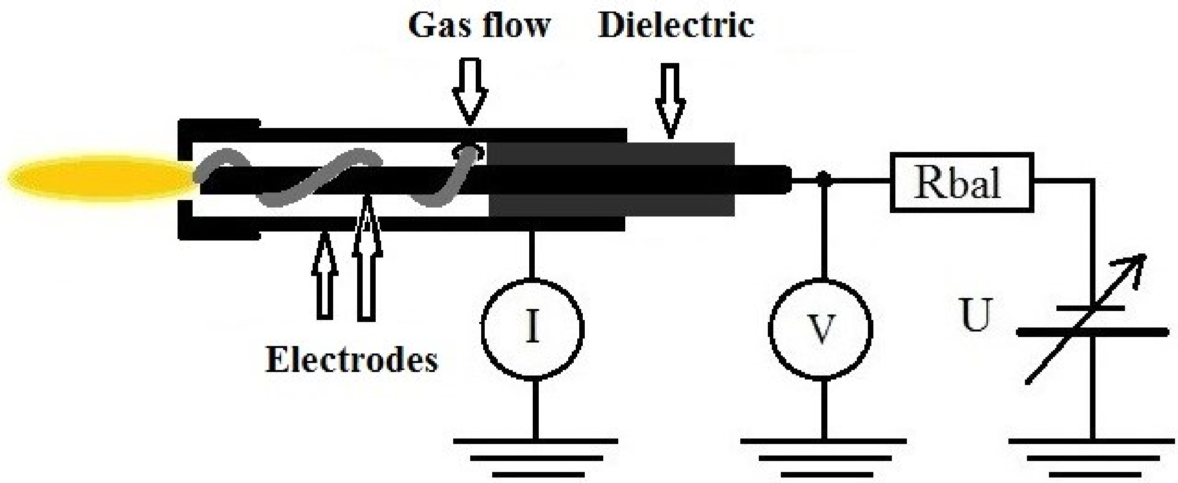

Fig.1: Electrical scheme for generation of atmospheric pressure microplasma jet

3 RESULTS

The current-voltage characteristics (CVC) measurements of microdischarge were performed for different air flows (G = 1 ÷ 4 L/min). Also different output diameters (from which microdischarge jet was blown out) were used by using different caps: from d = 0.5 mm to d = 2.0 mm with step of 0.5 mm. The measurement results of CVC with the positive potential of the high voltage electrode are presented in Fig.2. As in previous work [2], the extreme points on the ordinates axis correspond to the breakdown voltage.

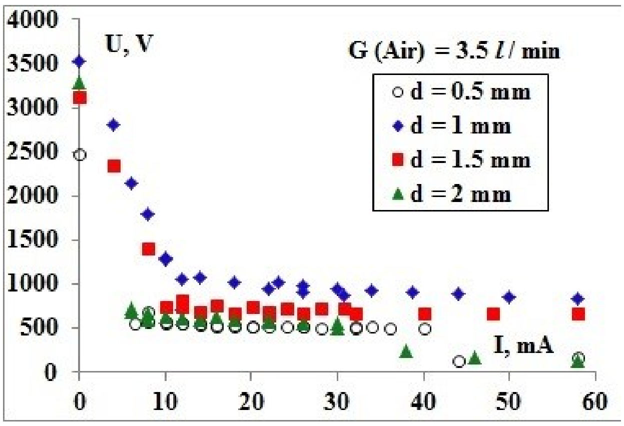

Fig.2: Current-voltage characteristic of the microdischarge which were blowing thru the hollow d (0.5-2 mm) with gas flow G = 3.5 l / min. Working gas – air

As it can be seen from the Fig. 2, the CVC has monotone character and the voltage decreases with outlet diameter d increasing, except in the case of output diameter d = 0.5 mm. The same characteristic was observed for another gas flows.

Optical emission spectroscopy of plasma-generated microplasma jet was made by CCD-based spectrometer Solar TII (S-150-2-3648 USB) in the wavelength range of 200 – 1100 nm with spectral resolution of approximately 0.2 nm.

Typical emission spectra of microjet plasma in the wavelength range of 200 – 650 nm and in the wavelength range of 650 – 1100 nm are shown on Fig.3 and Fig.4 respectively. Both spectra are normalized at maximum. Molecular N_2 band in wavelength range of 335 – 339 nm and atomic oxygen multiplet on wavelength 777 nm are distorted by too large intensity. It should be noticed that intensity of UV part of emission spectra is by 3-4 orders more intense than its IR part.

Emission spectra of the microplasma are multicomponent. The presence of atomic oxygen multiplets (777, 844 and 926 nm) and molecular bands of NO, OH, N_2 (B-A) and N_2 (C-B) and also N_2^+ is shown.

The N_2 molecular bands are the most intensive in comparison to others molecular spectra. For that reason N_2 molecular bands were used for the determination of vibrational (T_v^*) and rotational (T_r^*) temperatures of plasma components. The temperatures of N_2 molecules were determinate by comparing the experimental spectra with spectra simulated in Specair code. The Fig.5 shows comparison of experimentally measured spectra with N_2 (C-B) spectra simulated with program code "Specair".

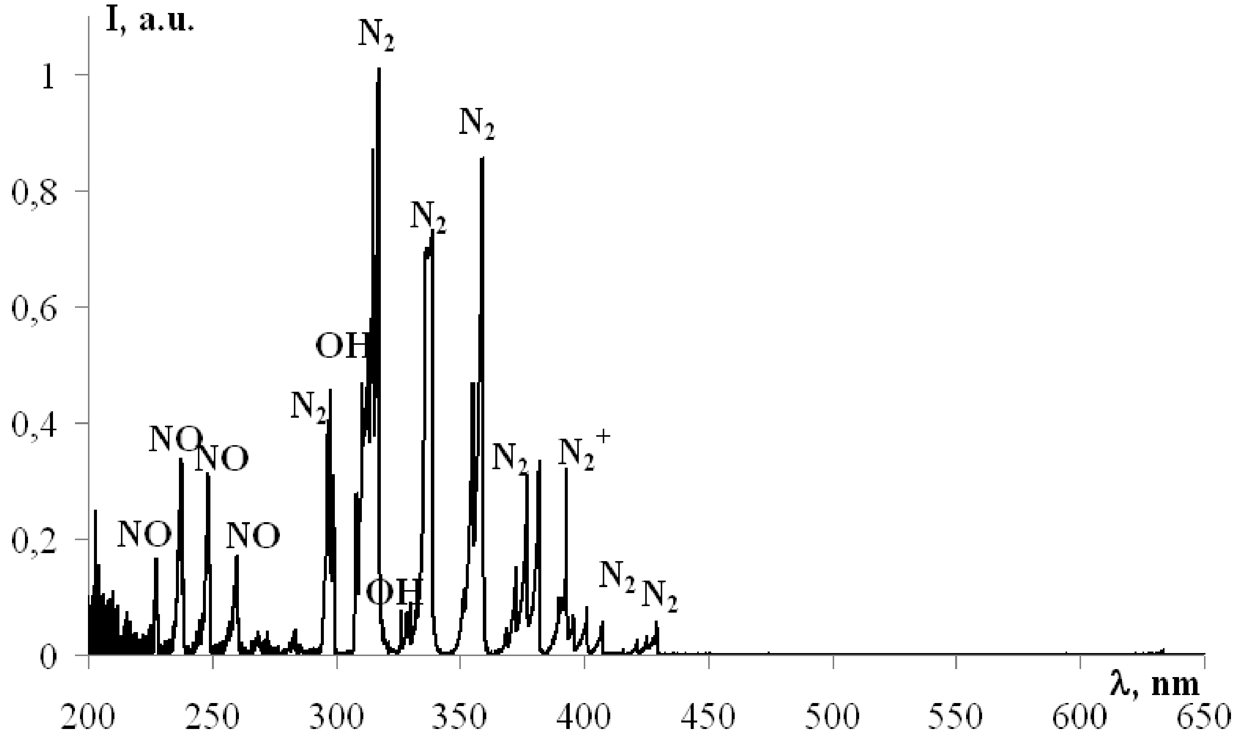

Fig.3: Typical emission spectra of microjet plasma in the wavelength range of 200 – 650 nm

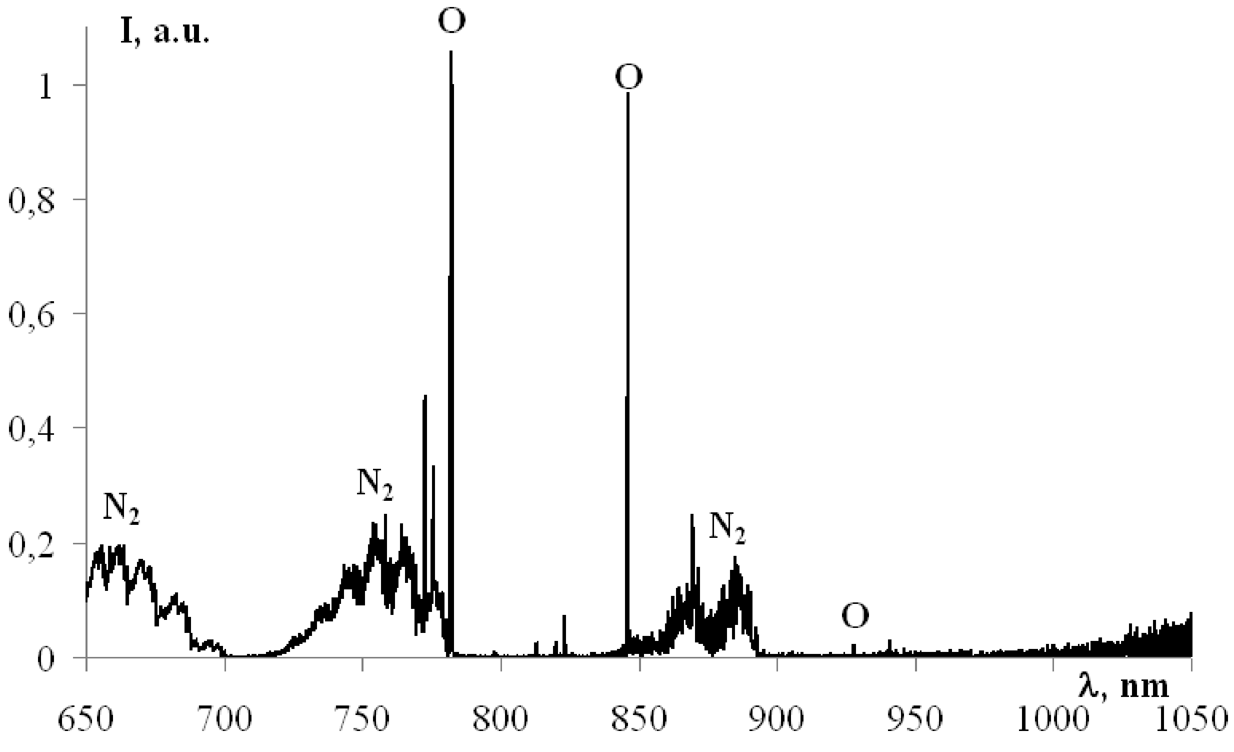

Fig.4: Typical emission spectra of microplasma jet in the wavelength range of 650 – 1100 nm

The plasma discharge was diagnosed at different discharge currents (20 and 30 mA) and along the plasma jet height (z). The air flow was 3.8 L / min.

The oxygen $T_e^*(O)$ has been defined via the Boltzmann plots method. The three most intense multiplets (777.2 nm, 844 nm, 926 nm) and data from [3] are used in this method. It was found $T_e^*(O) = 3000$ K. The error of T_e^* definition is approximately

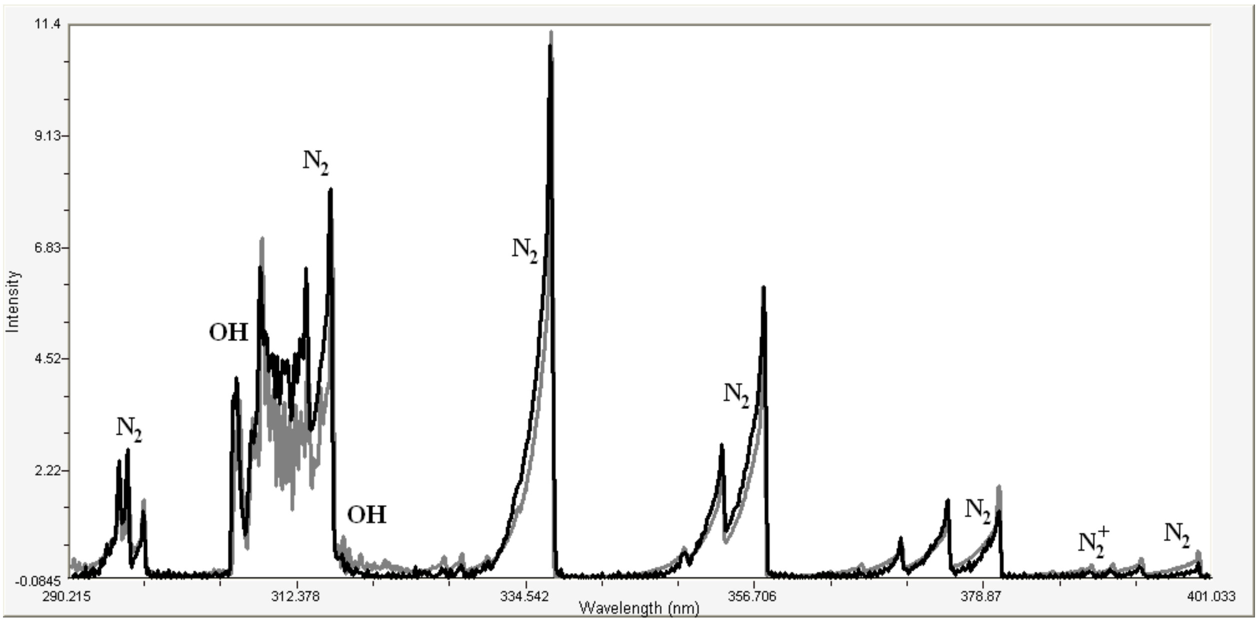

Fig.5: Experimental emission spectrum (black spectrum) of microplasma jet and its comparison with spectra simulation (gray spectrum)

1000 K, so we can say that the components temperature has low dependence on current.

Axial temperatures (T_v^* and T_r^*) distribution for N_2 under different current (20 and 30 mA) is presented at Fig.6 in case of output diameter of system – d = 1.5 mm.

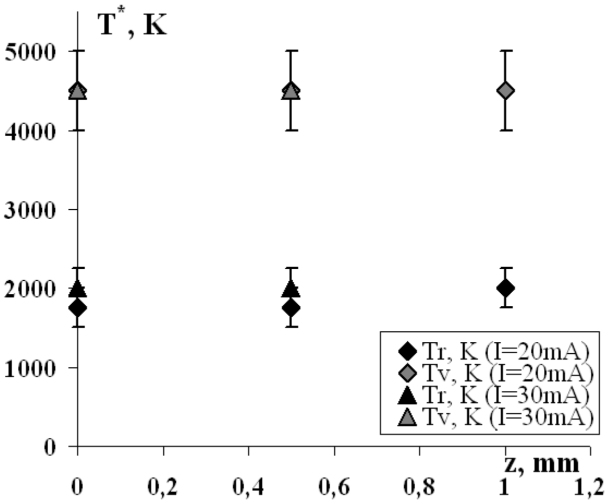

Fig.6: Axial distribution of N_2 (C-B) vibrational and rotational temperatures along the outside part of plasma jet. There z = 0 mm shows the temperatures of microplasma near the output hollow of the grounded electrode.

The temperatures $T_r^*(N_2)$ increased slowly (within the error margin) with height of the plasma jet while $T_v^*(N_2)$ remains constant. The temperature T_v^* of N_2 molecules, within the error margin, does not change with the changes of current. However, $T_r^*(N_2)$ increased slowly within the error margin.

4 CONCLUSIONS

- The non-monotonously voltage drop depends on the output diameter of the system.
- The atomic oxygen lines and NO, OH, N_2 and N_2^+ molecules were presented in the emission spectra of the microplasma.
- The temperatures $T_v^*(N_2)$ and $T_e^*(O)$ do not change with changes of current. However, $T_r^*(N_2)$ increased slowly within the error margin.
- The temperature $T_r^*(N_2)$ is slowly increasing with along the axis of the plasma jet while $T_v^*(N_2)$ remains constant.

Acknowledgements

This work was partially supported by Ministry of Education and Science of Ukraine, National Academy of Sciences of Ukraine, and Taras Shevchenko National University of Kyiv.

REFERENCES

[1] Herrmann H W, Henins I, Park J, Selwyn G S, Phys. Plasmas 6 (1999) 2284-2289.
[2] Solomenko Ok V, Lendiel V V, Chernyak V Ya, et al. Probl. Of Atom. Sci. and Techn. Series: Plasma Physics 20 (2014) 241 - 244.
[3] Czernichowski A, In: 19th Int. Symp. on Plasma Chem. Bochum, Germany, 2009, 1-4.