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CHARACTERIZATION OF NEON PLASMA JETS GENERATED BY DIELECTRIC BARRIER DISCHARGE-LIKE SYSTEM AT ATMOSPHERIC PRESSURE

Neslihan ŞAHİN[1,*], Murat TANIŞLI[1]

[1]Department of Physics, Faculty of Science, Eskişehir Technical University, Eskişehir, Turkey

ABSTRACT

In this study, neon plasma jets were generated by dielectric barrier discharge-like (DBD-like) system using alternative current (AC) power supply at atmospheric pressure. The optical emission spectroscopy allowed to characterize plasma jet. The optical emission spectra were recorded to determine the properties of plasma jets with different AC voltages and neon gas flow rates. The spectra of neon plasma jets were analyzed by comparing them with the data obtained from National Institute of Standards and Technology (NIST). The results show that intensity of the spectral lines of plasma jets increases with increasing voltage applied to neon gas. In addition, neon plasma jet length was investigated for different conditions. By varying the gas flow rate of neon while the power input and frequency are kept constant, it is observed that the plasma jet length ranges from about 1.0 to 2.2 cm.

Keywords: Atmospheric pressure plasma jet, Dielectric barrier discharge-like system, Optical emission spectroscopy

1. INTRODUCTION

Plasmas in the laboratory conditions can be classified as atmospheric pressure and low-pressure plasmas. The application of atmospheric pressure plasma jets is of great interest in areas such as industrial application and biomedical fields. Atmospheric pressure plasma systems do not need extra equipment such as vacuum chamber and pumping system so it is very easy to use in terms of cost and simplicity of application areas. Discharge characteristics are important because it is used in different applications.

Plasma jets can be designed in various categories with different configurations. They can be named as dielectric-free electrode jets, dielectric barrier discharge (DBD) jets, DBD-like jets and single electrode jets. In DBD-like systems, which are one of these systems, the configurations are in the form of a single wire or a hollow electrode in dielectric and a ring electrode out of dielectric. In here, the task of the outer ring electrode is to provide the advantage in DBD systems. The basis of these discharges is that the plasma jet acts as DBD when it does not come into contact with any object or surface. However, when the plasma contacts an object with electrical conductivity, discharge begins to occur between the high voltage electrode and the applied object. Therefore, such systems cannot be operated for as long as DBD systems. Alternative current (AC) with kHz frequency, pulsed direct current (DC) and radio-frequency (RF) power supply can be used to generate plasma jet [1]. DBD-like systems can be used in the health field. They can be treated to a cell or an entire tissue. These systems have the arc risk. This forces the use of the discharge systems. However, DBD-like systems have their own advantages. If dielectric is to be used, more power can easily be transmitted to the plasma applied to conductive materials [2].

In this study, neon DBD-like jet at low temperature is examined at atmospheric pressure. It is seen from study that optical emission spectra are especially recorded and analyzed. The paper is outlined as follows: In section 2 we go through a brief overview of the experimental details. In section 3 we briefly

*Corresponding Author: neslihansahin@eskisehir.edu.tr
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present the results about optical emission spectroscopy (OES) measurement and length of the plasma jet. In conclusion the importance of the study is emphasized.

2. EXPERIMENTAL SETUP

The plasma jet system was selected as the DBD-like system. The experimental scheme of the discharge formed through the AC power supply was also given in Figure 1. Plasma was obtained in quartz tube. The length, outer and inner diameters of quartz tube used to form plasma jet were 15, 0.52 and 0.41 cm, respectively. Plasma jet system consists of tungsten wire and aluminum circular electrode. The length of the tungsten wire is 17 cm. The radius and thickness of the aluminum electrode are 1.8 and 0.42 cm, respectively.

The neon gas flow rate was fixed to values between 1 and 6 L/min at atmospheric pressure. Neon discharge was obtained using high voltage AC power supply. The applied voltage and frequency values were recorded. The frequency of the used power supply was adjusted to be 24 kHz. AC voltage was adjusted to values 4, 8, 12, 16 and 20 kV. Ocean Optics HR2000+ was used to determine the optical properties of neon plasma jet with OES results for discharge in the wavelength range of 200-1100 nm. OES measurements were recorded at a distance of 1 cm from the quartz tube. OES measurements of neon plasma jet obtained by changing parameters such as input voltage, frequency and gas flow rate were evaluated and also the length of plasma jet was also tried to be measured for these conditions.

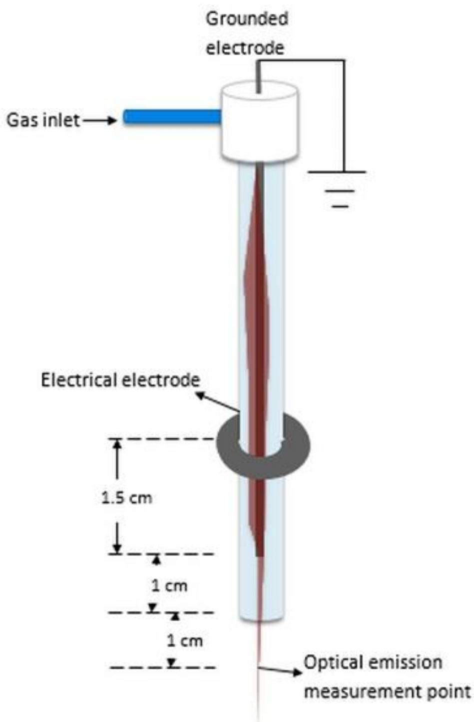
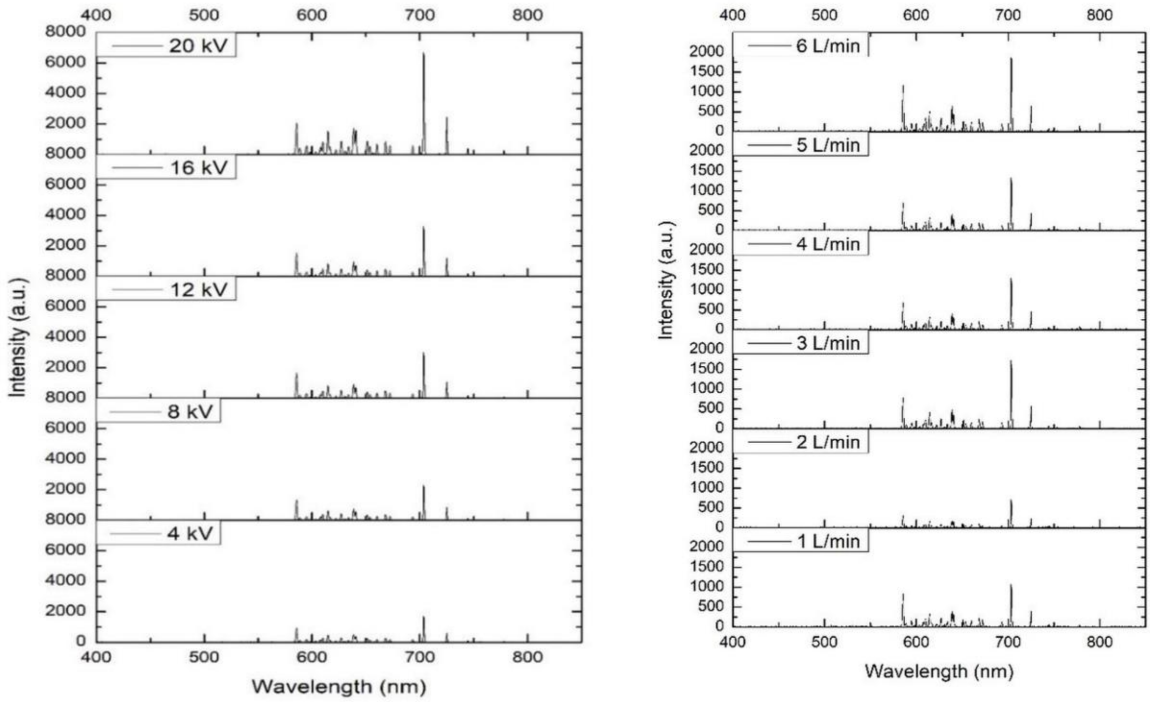


Figure 1. Experimental setup for dielectric barrier discharge-like jet

3. RESULTS AND DISCUSSION

The optical emission spectroscopy measurements include upright position from a single point of plasma jet located 1 cm away from the bottom of the quartz tube. The spectra have been recorded for different voltages and gas flow rates. When the electric power is applied to gas, the electric field effects on gas. Electrons accelerate in the system. The accelerated electrons can excite or ionize neutral atoms through electron collisions. Therefore, optical emission spectroscopy measurements can give exclusively information about the species of the plasma. Figure 2 shows the emission spectrum of the neon DBD-like plasma jet collected by Ocean Optics HR2000+ in the between 200 and 1100 nm with 100 ms integration time. These spectra of the pure neon plasma jet have neon atomic lines. Neon lines appear in the wavelength range 600-800 nm. Emission spectral lines are determined from National Institute of Standards and Technology (NIST) [3]. Most intensive emission lines can be listed as 585.2, 609.6, 614.31, 626.6, 633.4, 640.2, 650.7, 667.9, 671.7, 692.9, 703.2 and 724.5 nm. Maximum emission is observed when 20 kV AC voltage is applied to 3 L/min gas flow rate of neon. The spectra can include hydrogen and oxygen-related impurities. It can be seen that the spectra have not oxygen (OI) emission line at 777 nm. The Second Positive System (SPS) rotational-vibration lines of N_2 and the First Negative System (FNS) lines of N_2^+ have not been recorded in the 330-450 nm wavelength range [4]. The neon emission lines have occurred across the spectrum. As the voltage applied to the gas increases, the spectral line intensity of the plasma jet continued to increase.

The plasma jet cannot be observed very well for the low voltage applied to gas. However, the increase in the applied voltage causes the plasma to form easily. Thus, the length of plasma jet increases. As the voltage applied to gas increases, the electron energy and impact cross section increase significantly. In addition, more electron and excited states can be generated in the plasma jet. This causes an increase in the intensity of emission lines [5, 6].



(**a**) (**b**)

Figure 2. Optical emission spectroscopy measurements for (a) different voltages at constant frequency and flow rate (b) different flow rates at constant frequency and voltage

Plasma jet length has been measured when the gas flow rate is increased and other parameters are constant. Figure 3 shows the variation of the jet length with the flow rate. It is much longer for 3.5 and 4 L/min compared to other measured flow rates. The length of plasma jet is initially increased when flow rates become higher. When the flow rate is 4 L/min, the length reaches a maximum value of about 2.2 cm. To generate a plasma jet in atmospheric pressure, the maximum length of neon plasma jet can be determined by the diffusion of the surrounding air in the plasma jet. It can be observed that plasma jet length increases during the increase of gas flow rate up to 3 L/min. However, spectral line intensities decrease with increasing flow rate. Conversely, while flow rate is increasingly changing from about 3 to 6 L/min, the length of the jet decreases. In this case, spectral line intensities increase generally.

The electric field and the number of electrons occur incrementally with the increase of voltage applied to the gas. The number of particles exiting outside the tube increases. This causes an increase in the length of the jet. In addition, as the gas flow increases further, the speed and pressure of the particles in the plasma to escape out of the tube increase. The thickness of the plasma jet begins to increase. This is the reason that after 4 L/min gas flow rate the length of the jet starts to shorten and the thickness increases.

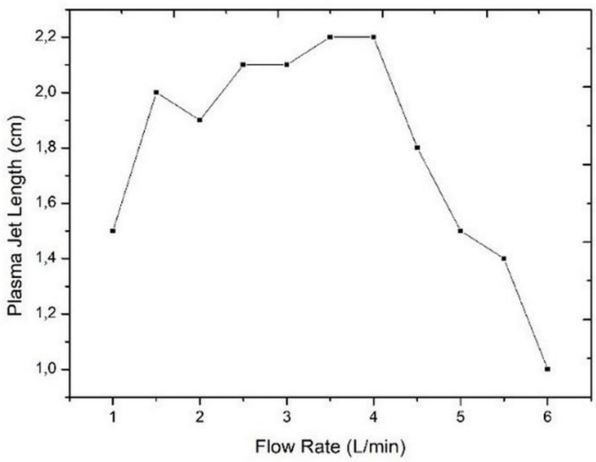


Figure 3. The changes of neon plasma jet length via gas flow rate at 24 kHz frequency and 12 kV voltage

4. CONCLUSION

Dielectric barrier discharge-like plasma jet operated at 24 kHz AC voltage has been generated at atmospheric pressure. The emission spectra and jet length were measured. The effects of the AC voltage applied to gas and gas flow rate on plasma properties have been studied. In neon plasma, the difference of energy level causes to generate ions or metastable species. OH emission bands, nitrogen bands and oxygen spectral lines are not seen in the spectra. Neon emission lines become stronger for the higher AC voltage. At the same time, the most intense spectral lines have been obtained for 20 kV voltage and 6 L/min flow rate. The increase in the intensity of the spectral line causes the plasma density to increase. It means that the higher AC voltage leads to increase in the number of the charged particles, and also the increase in flow rate gives the same result. It is observed that the plasma jet length depends on the gas flow rate. For higher and lower flow rates, the plasma jet gets troubled and its length decreases. The results show that the length of plasma jet depends on flow rates of gas. The longest plasma jet with a fine tip was obtained for about 3.5 and 4 L/min gas flow rate for AC power at 24 kHz frequency and 12 kV voltage. However, the thickness (radius) of plasma jet is higher for other flow rates. Therefore, the quenching of metastable species causes the tip of plasma jet to disperse. In future studies, it will be tried to ensure stable operation of DBD-like discharges which can be used in various applications.

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