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ELECTRICAL AND SPECTRAL DIAGNOSTICS OF WATER FALLING FILM DBD IN NITROGEN AND AIR

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Abstract. An experimental study of coaxial dielectric barrier discharge (DBD) in gas and gas with water is presented. We have investigated electrical and spectroscopic characteristics of water falling film DBD in nitrogen and air at atmospheric pressure. The influence of applied frequency on discharge power and emission spectrum is studied in order to achieve the optimum working conditions of DBD reactor with water falling film and without water.

1. INTRODUCTION

A coaxial dielectric-barrier-discharge (DBD) was designed as atmospheric non-thermal plasma reactor for treatment of various water solutions (Kuraica et al. 2004). In this reactor water forms a falling film which is in direct contact with plasma. The plasma that is formed above the water besides ozone also has UV radiation, radicals (e.g. OH), excited atoms (e.g. O) and molecules, electrons and ions. Although the main interest in investigation of this type of discharges is application, there is also curiosity about the difference between the discharges in gas and gas with water. This paper presents our results in investigation of electrical and spectral characteristics of water falling film DBD in nitrogen and air.

2. EXPERIMENTAL SETUP

The reactor was originally designed and constructed in our laboratory. Nitrogen gas and ambient air were injected into the discharge volume with a flow rate of ~ 5 L/min. All measurements were done for a discharge reactor operating at an atmospheric pressure and room temperature.

A schematic diagram of experimental setup used in this study is illustrated in Fig. 1. The cylindrical reactor consists of two electrodes and a dielectric barrier. The dielectric is a quartz tube with the inner diameter of 25.7 mm, length of 500 mm and thickness 2 mm. The inner electrode is made of stainless steel with an external diameter of 21.3 mm and a length of 500 mm. An outer electrode made of stainless steel mesh (length 400 mm, optical transmission 45%) is wrapped around the quartz tube. Quartz tubes, inner and outer electrodes are placed concentrically. Barrier discharge is generated within ~ 2.2 mm gap between the inner metal electrode and the quartz tube. When the discharge source works as water falling film reactor, water flows up through a vertical hollow cylindrical electrode and flows down making a thin dielectric film over the electrode. Water flows from the reservoir through the discharge by use of peristaltic pump.

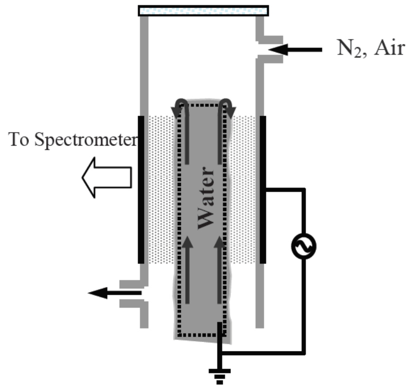

Figure 1: Experimental setup.

Filamentary DBD is generated in flowing nitrogen and air in the gap between the dielectric and the water layer by applying voltage of up to 20 kV, and the frequency varied from 50 to 450 Hz. The inner electrode is grounded via capacitor of 470 nF and the outer electrode is connected to power supply. The frequency and voltage in the primary of HV transformer were regulated by means of AC variable speed drive Emerson Commander SK (SKA 1200075). Electric parameters were measured and recorded using a digital oscilloscope Tektronix TDS 3032 (300MHz bandwidth, 2GSamples/s) and a high voltage probe Tektronix P6015A. Lissajous figures (Q-U graphs) were used for determination of electric power of the discharge.

Emission spectrum from the discharge transmitted through the stainless steel mesh was observed in the UV region. Integral spectrum is recorded with spectrometer Ocean Optics QE 65000 (wavelength range 200-400 nm).

3. EXPERIMENTAL RESULTS

The effect of applied frequency on discharge parameters is investigated. For all performed measurements primary voltage of transformer was set to the same value of 70V by means of AC variable speed drive. Fig. 2 and Fig. 3 show discharge power for different frequencies (50-450 Hz) for nitrogen and nitrogen with water, air and air with water, respectively. In the range from 50 to 300 Hz the discharge power increases with increase of frequency, then decreases. Dependence of discharge power on frequency is the same for gas and gas with water. Intensity of the light emitted from the discharge is maximal at 300 Hz.

During the experiment optimal operating conditions of DBD reactor were at a frequency of 300 Hz, therefore, the examination of discharge for different applied voltages was carried out at this frequency.

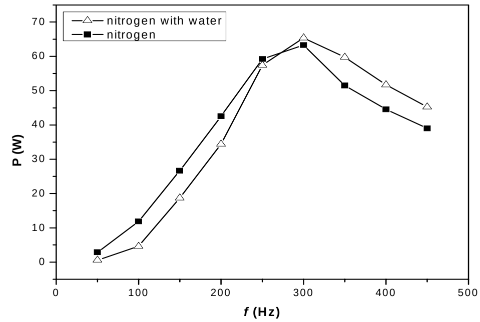

Figure 2: The effect of applied frequency on discharge power in nitrogen and nitrogen with water.

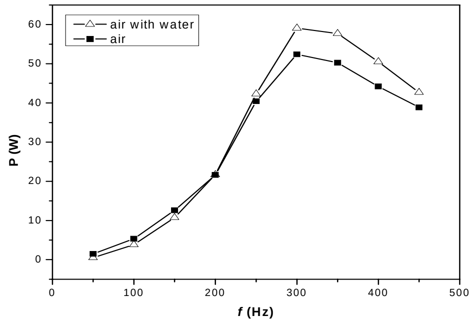

Figure 3: The effect of applied frequency on discharge power in air and air with water.

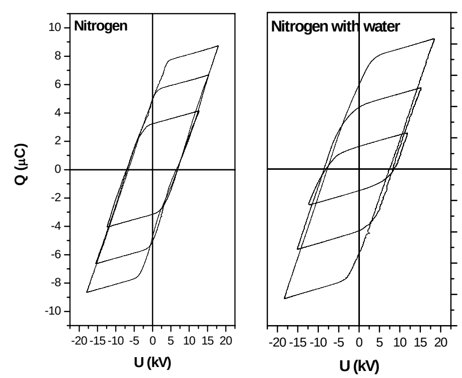

Figure 4: Lissajous figures obtained for different applied voltages for coaxial DBD in nitrogen and nitrogen with water.

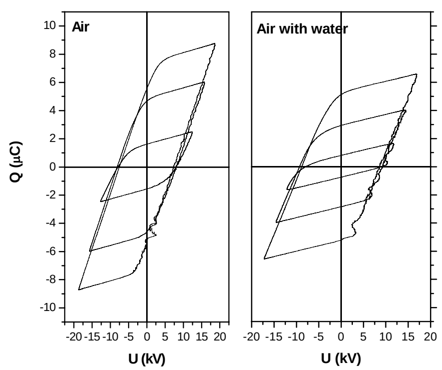

Figure 5: Lissajous figures obtained for different applied voltages for coaxial DBD in air and air with water.

Lissajous figures in Fig. 4 obtained for different applied voltages, at 300Hz, in discharge in nitrogen with water are wider compared to those obtained in discharge in pure nitrogen, which means that breakdown voltage increases in discharge with water. This can be explained by decreasing of nitrogen metastable density and will be subject of further investigations. Increasing of supply voltages has no influence on the breakdown voltage in the discharge with nitrogen. In the discharge with water, the increase of supply voltage decreases the breakdown voltage.

Fig. 5. shows Lissajous figures obtained in air without water and with water for different applied voltages at 300 Hz. For lower power supply voltage Lissajous figures have the shape of the parallelogram. However, with increasing applied voltage the shape becomes rather asymmetric, which is probably due to asymmetry of the discharge source. Similar to the discharges in nitrogen, breakdown voltage is higher in the discharge with water. In comparison with the discharges in nitrogen, discharges in air have larger breakdown voltages.

Fig. 6 and Fig. 7 represent emission spectra from DBD in nitrogen and nitrogen with water, air and air with water, respectively. Total intensity of all the bands in the range is lower from the discharge with water than from the discharge without water.

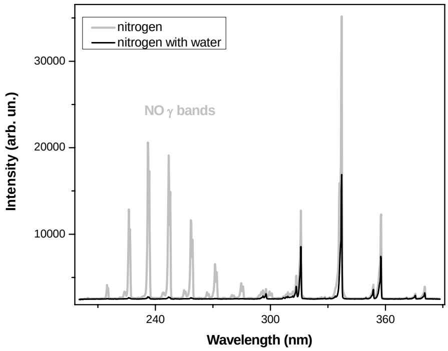

Figure 6: Emission spectra from coaxial DBD in nitrogen and nitrogen with water.

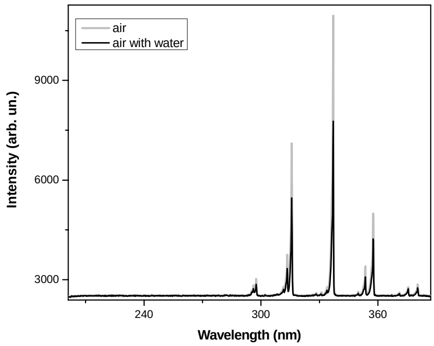

Figure 7: Emission spectra from coaxial DBD in air and air with water.

Emission spectra of nitrogen and air in the UV region consist mostly of the bands of molecular nitrogen (N_2 2nd positive system). In discharge in nitrogen bands of NO γ system were detected. In the discharge with water intensity of NO bands is significantly reduced in comparison with discharge without water. This could be explained by decrease of concentration of NO molecules caused by oxidation of NO to HNO_2 in humid atmosphere in DBD with water film. In such discharge, the H_2O molecule is dissociated and very reactive radicals O and OH are created which react with NO molecule in the following reactions (Orlandini et al. 2000):

$$NO + O + M^* \rightarrow NO_2 + M^* \quad (1)$$

$$NO + OH + M^* \rightarrow HNO_2 + M^* \quad (2)$$

Acknowledgements

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