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Investigation of electrical and optical properties of dielectric barrier discharge

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In this paper the results of optical and electrical characteristics of dielectric barrier discharge are presented where used “plane to plane” and “pin to plane” electrode configurations. The dynamic current-voltage characteristics of discharge at different electrode configurations were investigated. The plasma spectrum of air of dielectric barrier discharge was obtained by optical emission spectroscopy method. The results of measurement of the discharge current showed that the barrier discharge generated in the streamer mode, and the used pin electrode reduces the streamer channels and micro discharges. The plasma spectrum of air showed active components and radicals which can be used for treatment of living tissues and materials.

Key words: dielectric barrier discharge, dynamic current-voltage characteristics, plasma spectrum
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1 Introduction

The dielectric barrier discharge (DBD) is a discharge that is producedat atmospheric pressure between two metal electrodes, one of which is coated with a dielectric [1]. In recent decades, low temperature barrier discharge plasma is widely used for treatment of living tissues and destroy cancer cells [2, 3], for sterilizing instruments, packaging and seeds of various crops [4], to improve the surface properties of polymeric materials and textiles, as well as for deposition of various thin-films [5]. An important role in the generation of plasma at atmospheric pressure in dielectric barrier discharge plays a form of dielectric and metal electrodes. There are different geometric configurations of electrodes as "plane-to-plane", "pin-to-plane", "surface electrodes (surface DBD)", "co-axial arrangement of the electrodes," and etc. The electrode system determines the basic electrical, optical and energetic properties of the barrier discharge. In work [6] the AC corona discharge with barrier electrode was investigated experimentally. One of the electrodes had a flat geometry, which was covered with an insulator whereas the second electrode had the shape of the tip. Experiments were carried out at atmospheric pressure in air, helium, argon and nitrogen. The results showed that with pin like electrodes the breakdown voltage decreases in comparison with the plane to plane barrier discharge, but the current is considerably increase. Different modes of discharge at the pin-to-plane geometry of the electrodes were investigated in [7]. Various modes of discharge were obtained at an applied voltage of 3 kV and 6 kV and at the positive and negative half-cycles. It was shown that micro-glow discharges have a hierarchical structure like in a low-pressure glow discharge. In work [8] the characteristics of modified dielectric barrier discharge (i.e., pin-to-plane electrodes) in helium was studied in dependence on the applied AC voltage, the distance between two electrodes and the type of pin electrodes. The power consumption of the discharge was investigated at different densities of high voltage pin electrodes. In [9] the static current-voltage characteristics of the barrier discharge at pin-to-plane electrode configuration were studied and had been shown that the discharge current decreases with increasing the distance between the electrodes. In [10], the two-dimensional model of the barrier discharge in nitrogen for pin–to–plane geometry is made up based on the continuity equation and the Poisson’s equation for the electric field. The results of numerical analysis shown that the characteristics of the discharge determine by the distribution of variable electric field, which is more near from the pin electrode due to its curvature. For dissociation of carbon dioxide molecules the different geometry of electrodes of the barrier discharge reactor was used by authors in [11]. Application of pin-to-plane electrodes showed significant energy efficiency in comparison with the plane-to-plane electrodes.

2 Experimental setup

During development of the experimental setup based on a dielectric barrier discharge were collected two types of electrode system configurations. The first electrode system consists of two planar electrodes; one of them is coated with a dielectric material. In the second configuration, the ground electrode is replaced by a metal rod with a sharp tip, which gives the corona effect. The Figure 1 shows the general scheme of the experimental setup and the concept of a barrier discharge electrode systems.

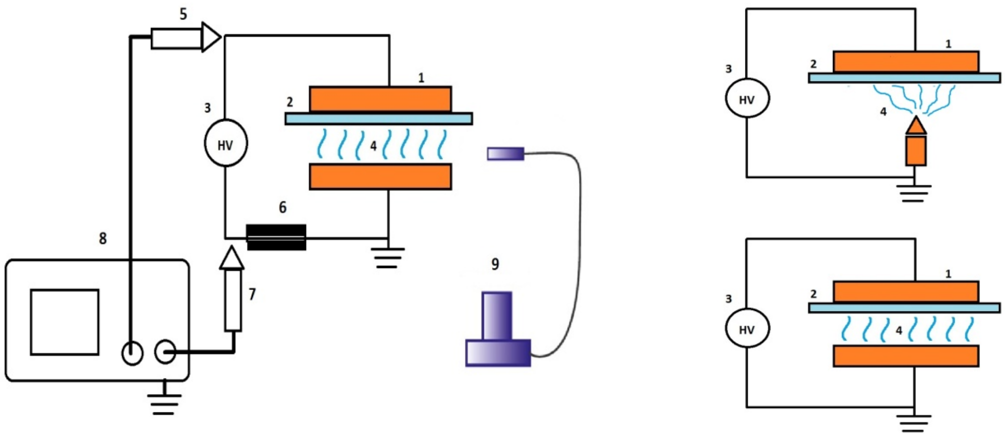

Figure 1 – The experimental setup and configuration of the electrodes of DBD

The copper cylinder (1) with a diameter d = 45 mm, and the thickness l = 4,5 mm used as planar electrodes. On a surface of a planar electrode the quartz glass (2) with a diameter d = 75 mm, thickness l =6 mm and a dielectric constant ε = 3,5 was disposed. In the case of the pin-to-plane configuration the sharp metal rod with length l = 28 mm and diameter d = 8 mm was used as ground electrode. In all experiments the interelectrode distance (4) was 2 mm. For generation of plasma we used the high voltage power supply (3), which generated the high voltage sinusoidal signal with amplitude 15 kV and frequency 20 kHz from. The applied voltage is measured using a high-voltage probe (5) Tektronix P6015 and a digital oscilloscope LeCroy (8). The current is detected by low-voltage LeCroy probe (7) and measuring resistor with resistance 100 Ohms (6). The optical characteristics were measured by optical emission spectrometer Solar Systems. The spectrometer consists of an optical system, an optical fiber for transmitting radiation from the spectrometer itself. Further, the resulting signal is processed by a personal computer. For visual observation of the discharge CCD camera was used with 25 frames / second.

3 Results and discussion

After applying a high-voltage sinusoidal signal, the barrier discharge at the filamentary mode formed between the electrodes on the flat dielectric surface and the metal. As shown in Figure 2, discharge consists of a set of microchannels (or streamers), which carries the discharge current.

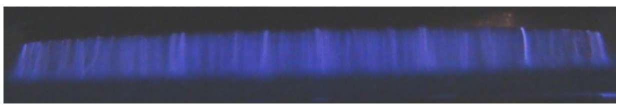

Figure 2 – DBD in operation at the "plane-to- plane" electrodes

Typically, in the case when one of the metal electrodes covered with a dielectric the width of microdischarge on the dielectric barrier surface were greater than on the surface on the metal electrode. Figure 3 presents the dynamic current-voltage characteristics of the discharge in a constant voltage 15 kV and at different electrode geometry. The left figure corresponds to the geometry of the "plane-to-plane" electrodes and the right corresponds to the geometry of the "pin-to-plane" electrodes.

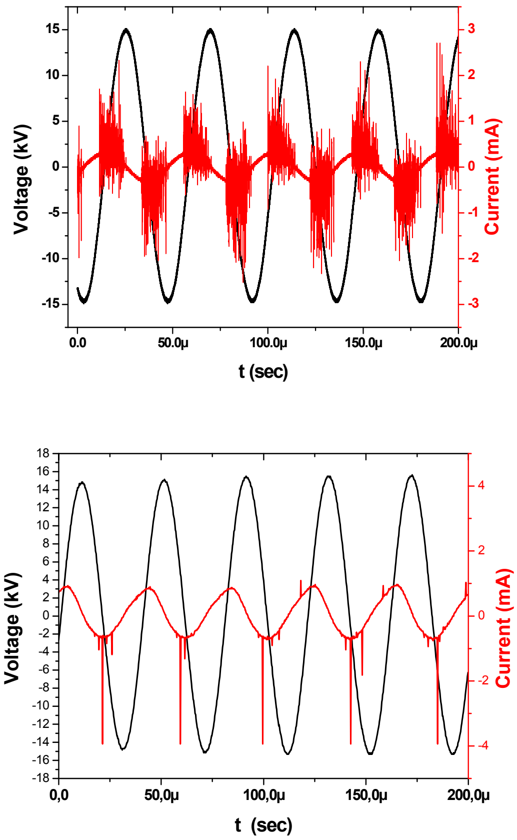

Figure 3 – The dynamic current-voltage characteristics of dielectric barrier discharge: the top –"plane-to-plane", the bottom – "pin-to-plane"

From the current waveform, it can be seen that in the case of “plane-to-plane” electrode geometry set of peaks observed at the start of each half-cycle of applied voltage. These peaks correspond to a plurality of multi microdischarge (streamer) in the discharge gap. In the case when a ground plane was replaced by a sharp metal electrode on the current waveform only single pulses can be seen. They correspond to a single streamer channel. It should be noted that the current through this channel is relatively high about 4 mA, whereas in the case of flat electrodesand the plurality of microdischarges current does not exceed 2.5 mA. Also it can be seen that at the “pin-to-plane” electrode geometry the current flows through the discharge gap only in the negative half-cycle voltage. This means the accumulation of charges on the plane electrode surface.

For determination of the active chemical species of barrier discharge the plasma spectrum of air was measured in the range from 200 nm to 1200 nm under an applied dc voltage of 15 kV and atmospheric pressure. The results showed the presence of nitrogen and oxygen lines. The main active components of the plasma are N^2 and N^{2+} and atomic oxygen. Also, there is a compounds of NO and OH. These spices are basis for treatment of living tissues, cells, and they have the disinfection effects. Figure 4 shows the plasma spectrum obtained at the “plane-to-plane" electrode geometry.

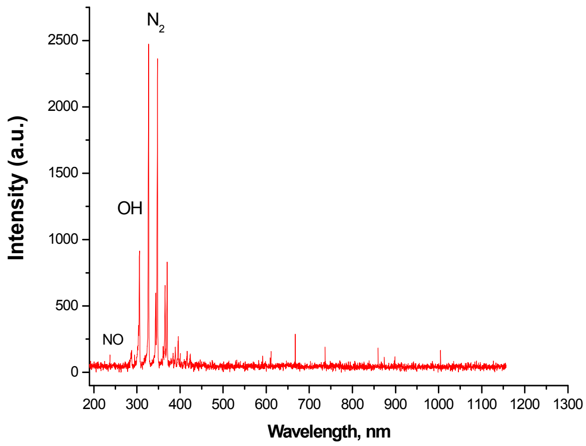

Figure 4 – The plasma spectrum of air at an applied voltage of 15 kVat “plane-to-plane” electrodes.

4 Conclusion

The dynamic current-voltage characteristics of dielectric barrier discharge and the plasma spectrum of at “plane to plane” and “pin to plane” electrode configurations were obtained. It is shown that the applied pin electrode reduces the number of streamer channels and the flow of the main current is only in the negative half-cycle of the voltage. The results of optical emission spectroscopy showed a decrease of the plasma intensity at the “pin-to-plane” electrodes. The experimental results can be useful in the study of the physical processes in varying combination with DBD electrode geometry.

Acknowledgments

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