ANODE CURVATURE INFLUENCE ON CHARACTERISTICS OF NEGATIVE CORONA DISCHARGE UNDER TRICHEL PULSED MODE

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Experimental investigations of electrodynamics characteristics of negative corona discharge in air under Trichel pulsed mode are presented. The influence of anode dimensions and curvature on discharge current parameters in strongly non-uniform electric field was studied. It was shown that at the same conditions the decreasing of anode curvature causes the increasing of current pulses frequency. At the same time the parameters of Trichel pulses remain constant for different anode curvatures. The increasing of average discharge current value under decreasing of anode curvature also observed. It is necessary to note that the variation of anode dimensions has a proportional action on current pulses frequency; however it is observed only in a certain range of the applied voltage.

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1. INTRODUCTION

The research on non-equilibrium gas discharges at atmospheric pressure looks very attractive at present, because the pace of progress in modern plasma chemistry technologies depends on it for their successful practical uses [1].

Negative corona discharge at atmospheric pressure can exist in different forms depending on configuration of the electrodes and amplitude of applied voltage. In a certain voltage interval, starting with the discharge ignition voltage, the discharge current transforms into a steady train of pulses which became known as the Trichel pulses [2], and when the voltage achieves a certain value the discharge transits into the diffusion stage [3]. Experimental studies on the negative corona current characteristics in the Trichel pulse regime were made in references [4-6]. There the focus of attention was pinpointed on the determination of physical processes responsible for the Trichel pulse formation in various gases. The numeric simulations of the formation of the Trichel pulses in the air, as made in reference [7], allowed the researchers to reproduce the Trichel current pulse train. Then, the calculated time parameters of individual Trichel pulse agreed well with experiment, but for the pulse repetition frequency obtained during the modelling which diverged from experimental data.

A study on the influence of the electrode system geometric parameters on discharge characteristics may well point out such processes that might pertain to the space charge relaxation and get their interrelationship with the current characteristics established. This would call for an experimental study of the discharge current characteristics while using plane and spherical anodes of different diameters.

2. EXPERIMENTAL SETUP

The experiments were carried out on a plant the schematic of which is shown in Fig. 1. The cathode was a copper needle with the nose radius 50 µm. Either a sphere, or a flat disk were used for anode. The sphere was made of stainless steel. Such spheres were used that had the diameters of 6, 8 and 13 mm. The flat disk was also made of stainless steel. Disks of 10, 20 and 32 mm in diameter were used. The interelectrode space in all experiments was 10 mm. The voltage was applied to the electrode system from the stabilized DC 0.5…20kV voltage supply and was measured with LeCroy PPE20kV HV probe.

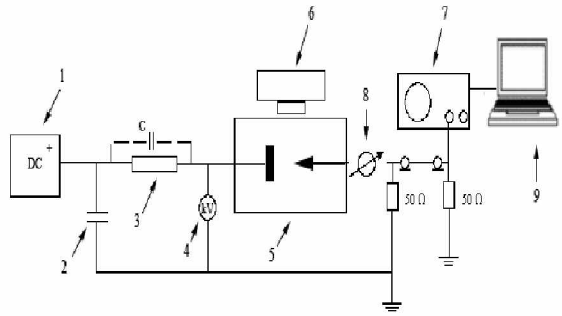


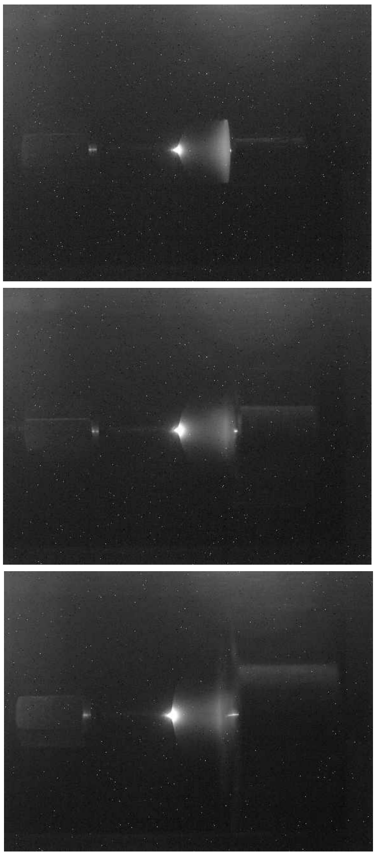
Fig.1. Setup of experimental test bed: 1 – HV stabilized power supply, 2 – Voltage capacitive filter, 1000 pF, 3 – Ballast resistor (capacitive resistive impedance of TBO type with nominal value 130 kΩ), 4 – HV probe LeCroy PPE20kV, 5- Discharge cell, 6- Photographic camera Olympus C 7070, 7- Oscillograph Tektronix TDS-2024B , 8- Microammeter M906, 9- Computer

The positive potential was fed to the flat electrode, while the needle-shaped electrode was at earth potential. The discharge average current was measured with M906 microammeter. To register the discharge current pulse waveforms, the discharge circuit had a bypass installed in it with the nominal value 50 Ω, from which the signal was fed to the input channel of Tektronix TDS-2024B four-channel oscillograph with the bandwidth 200 MHz and sampling rate 2 GHz. In order to control the stable discharge burning regime, while doing the studies, the oscillograph was used to monitor the discharge pulse waveforms and measure the current pulse repetition frequency.

In the experiments, for each voltage value in the range under study and for different anode diameters oscillograms were taken of the discharge current pulses, with the current pulse repetition frequency measured, photographic images of the discharge taken using Olympus C7070 photocamera.

3. EXPERIMENTAL RESULTS

The experiments, carried out using either plane or spherical anodes with different diameters, allowed to determine the effects of anode geometrical dimensions on electrodynamic characteristics of the discharge. Fig. 2 presents pictures of the negative corona for three different diameters of plane anode. The voltage in the discharge gap was U= 7 kV, the interelectrode space – 10 mm.



a

b

c

Fig. 2. Negative corona photographic images for taken different diameters of plane anode. The exposure is 1 min. The discharge gap voltage is U=7kV, the interelectrode space 10 mm. a) The plane anode diameter is d=10 mm, the discharge average current I_{av}= 24 μA, the current pulse train period T=2.5 μs; b) d=20mm, I_{av}= 36 μA, T=2 μs; c) d=32 mm, I_{av}= 42 μA, T=1.6 μs

The above images indicate that upon increasing the anode diameter the glow intensity in the near-anode region decreases, with the current pulse train period decreasing as well, while the average discharge current goes up.

While using spherical anodes with different diameters, also observable were an increasing radiation intensity from the near-anode region upon decreasing the anode diameter and a change in the current pulse repetition frequency. Fig. 3 gives photographic pictures of the negative corona for different diameters of the spherical anode. The discharge gap voltage here is U = 11 kV, the interelectrode space 10 mm.

From the data series that correspond to the pictures in Fig. 3 one can gather that upon increasing the anode diameter the current pulse train period goes down and the average discharge current goes up. However, when the discharge gap voltage is U=11.9 kV, the tendency for the current characteristics to vary becomes blurred or it is not observable at all. In particular, when the spherical anode diameter is d = 6 mm, the current pulse train period is T = 1.5 μs, and increasing the anode diameter up to d = 13mm acts to reduce the current pulse period down to T = 1.7μs.

a

b

c

Fig.3. Photographic pictures of negative corona at different diameters of spherical anode. The exposure is 1 min. The discharge gap voltage is U=11kV, the interelectrode space 10 mm. a) The spherical anode diameter is d=6 mm, the average discharge current I_{av}=21 μA, the current pulse train period T=3.8 μs; b) d=8mm, I_{av}= 23 μA, T=2.7 μs; c) d=13mm, I_{av}= 26 μA, T=1.9 μs

This barely noticeable change in the current pulse repetition frequency may well result from a low instability in the discharge burning and has nothing to do with the anode size variation. This result indicates that there is a certain voltage range in which the anode dimensions start acting on the electrodynamic characteristics of the discharge. It should be stressed here that the discharge current pulse remains unchanged at different diameters of the anode which makes for rejection of the Trichel pulse effects and related processes from consideration.

Fig. 4 gives the oscillograms of the Trichel current pulses for different diameters of the spherical anode and voltage in the discharge gap U=11kV.

From the oscillograms on Fig. 4 it follows that the Trichel current pulse waveform remains unchanged and so does the current pulse amplitude. The unchanged current pulse waveform indicates that changing anode size does not tell on the Trichel pulse characteristics, although it does have its effect in a certain voltage range on the current pulse repetition frequency.

This result indicates that the current pulse repetition frequency may be determined by the relaxation rate of the negative space charge stored in the discharge gap in-between pulses, the anode size determining the intensity of the concomitant processes.

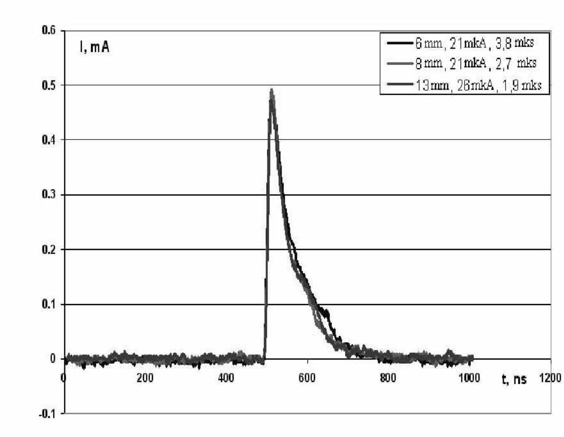


Fig. 4. Waveforms of discharge current pulses. The discharge gap voltage is U=11kV, the interelectrode space 10 mm. a) The spherical anode diameter is d=6 mm, the average discharge current I_{av}= 21 µA, the current pulse train period T=3.8 µs; b) d= 8mm, I_{av}= 21 µA, T=2.7 µs; c) d=13mm, I_{av}= 26 µA, T=1.9µs

CONCLUSIONS

1. Experimentally studied the effect of anode size on the current characteristics of the negative corona in the Trichel pulse regime. It is established as fact that the anode size acts dramatically on the current pulse train period, with the characteristics of individual current pulses remaining unchanged. Upon increasing the anode diameter, the average discharge current also grows.
2. Research results indicates that the current pulse repetition frequency may be determined by the relaxation rate of the negative bulk charge stored in the discharge gap in-between pulses, the anode size determining the intensity of the concomitant processes.
3. Determined are the experimental conditions in which the anode dimensionality influences substantially the electrodynamic characteristics of the discharge. In particular, a voltage range was defined in which the tendency of variation of the discharge current characteristics is to be expected.
4. Researched are the spatial characteristics of the radiation from the near-anode region at different radii of the anode curvature. It was shown, that radiation intensity from the anode area considerably depends on anode shape. It was observed that upon increasing the anode diameter the glow intensity in the near-anode region decreases.

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ВЛИЯНИЕ КРИВИЗНЫ АНОДА НА ХАРАКТЕРИСТИКИ ОТРИЦАТЕЛЬНОЙ КОРОНЫ В РЕЖИМЕ ИМПУЛЬСОВ ТРИЧЕЛА

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Представлены результаты экспериментальных исследований электродинамических характеристик отрицательной короны в воздухе в режиме импульсов Тричела. Показано влияние кривизны анода на частоту следования токовых импульсов. В частности, было установлено, что при уменьшении кривизны анода частота следования токовых импульсов увеличивается, при этом характеристики отдельных токовых импульсов Тричела остаются неизменными. Следует отметить, что изменение частоты следования токовых импульсов происходит пропорционально изменению размеров анода, однако, только в некотором диапазоне напряжений на разрядном промежутке.

ВПЛИВ КРИВИЗНИ АНОДА НА ХАРАКТЕРИСТИКИ НЕГАТИВНОЇ КОРОНИ У РЕЖИМІ ІМПУЛЬСІВ ТРИЧЕЛА

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Представлено результати експериментальних досліджень електродинамічних характеристик негативної корони у повітрі в режимі імпульсів Тричела. Виявлено вплив кривизни аноду на частоту токових імпульсів. Було встановлено, що при зменшенні кривизни аноду частота токових імпульсів зростає, в той же час характеристики окремих токових імпульсів Тричела залишаються незмінними. Треба підкреслити, що зміна частоти токових імпульсів відбувається пропорційно зміні розмірів аноду, але лише у деякому діапазоні напруг на розрядному проміжку.