ELECTRICAL AND OPTICAL CHARACTERISTICS OF DIELECTRIC-BARRIER DISCHARGE DRIVEN BY HIGH VOLTAGE NANOSECOND GENERATOR.

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Introduction

One of the well-known industrial applications of the electrical barrier discharge is plasmachemistry and ozonator technology. A new interesting and perspective application of this type of discharge is the effective pumping of high intensity UV light sources for microelectronics industry, air and water desinfection, photochemistry, etc. [1, 2]. Usually the barrier discharge is powered by the voltage of sinusoidal waveform with the frequencies ranged from 50 Hz - 10 kHz and up to 50 kV amplitudes. It is a very perspective to use the high voltage nanosecond pulse generators for barrier discharge initiation. Impulse power supply permits to increase the overvoltage on discharge gap and as a consequence the reduced electric field strength E/N in the discharge plasma. The efficiency of atomic and molecular electronic levels excitation becomes higher. Also under applying pulsed voltage the discharge remains in homogeneous form in a wide range of experimental conditions.

In this work the results of the experiments on the barrier discharge characteristics in a large scale breakdown cell under supplying high voltage nanosecond pulses are presented. We paid particular attention to the discharge homogeneity and measurement of the energy dissipation in the discharge volume.

Experimental set-up and techniques

The experimental set-up layout as well as discharge system scheme is represented on fig.1. The discharge installation has coaxial geometry and includes the central electrode (1), the external grounded electrode (2) and quartz discharge cell (3). The discharge cell was constructed from two quartz cylinders sealed at the ends. The space between quartz cylinders - the discharge gap was 1 cm, the cylinder length and outer diameter were 100 cm and 9 cm respectively and the total volume of the discharge cell was 2300 cm^3. The central and external electrodes were made from the stainless still tubes of 3 cm and 15 cm diameter. The volume between central electrode and external one was filled with water as aqueous dielectric substance. Discharge installation has two water-quartz dielectric barriers. The value of effective dielectric constant of these barriers was 25 and overall capacity was $C_b \approx 1$ nF.

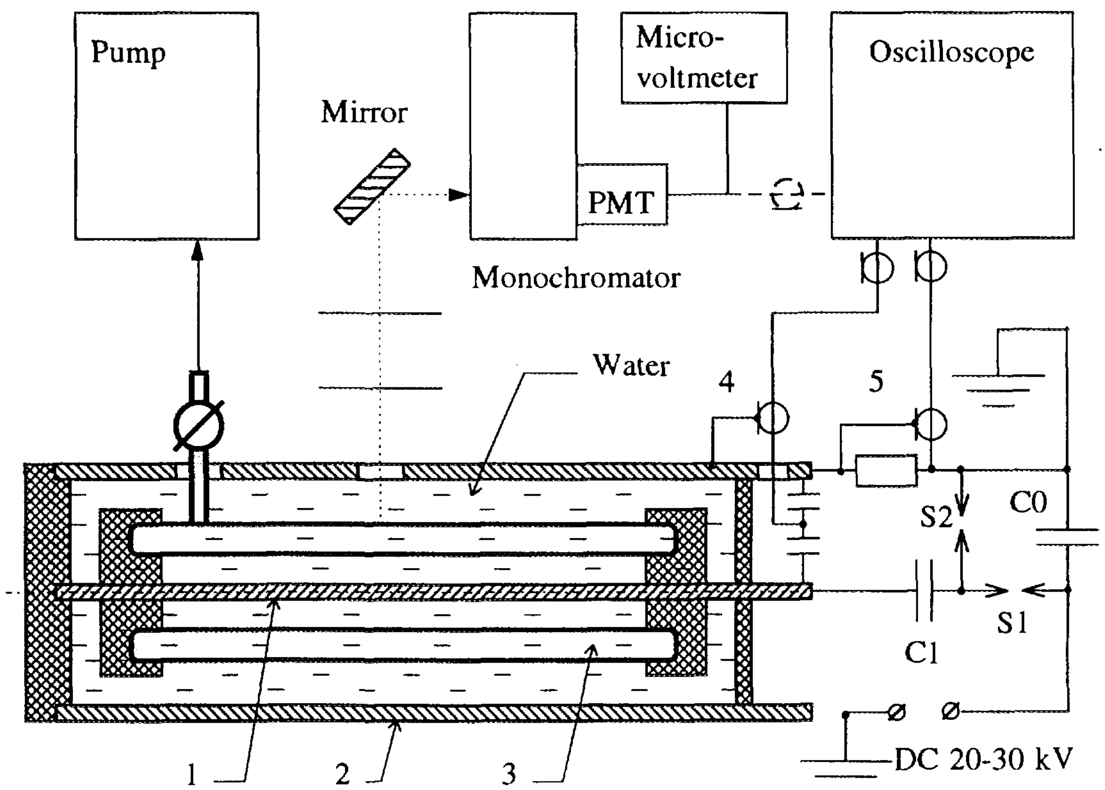

Fig.1 Experimental set-up layout.

High voltage pulses with nanosecond rise time were applied to the central electrode. The pulses were generated through two stages. During the first stage the storage capacitor C0 of 0.4 μF charged from DC power supply up to 20 - 30 kV was commutated by switch S1 to the high voltage electrode and discharge was turn on. When the capacitor C1 (1.7 nF) and capacity formed by dielectric barriers C_b were charged to supplying voltage, the discharge was turn off. The second stage was the commutation of the capacitor C1 and barrier capacity to the ground through the switch S2. Thus, two voltage pulses of opposite polarity were generated per one operation circle of the switches S1 and S2. The repetitive frequency of the switches was 600 or 1200 Hz.

In our experiments we made the synchronous independent registration of the voltage pulses U(t) on central electrode and the current pulses I(t) in the discharge circuit. For this purpose the capacitor divider (4) and current shunt (5) inserted in the grounded electrode circuit were used. Before the experiments the calibration of the voltage and current gauges were fulfilled. We removed the quartz cell from the discharge chamber and connected the central electrode to the grounded one through 50 Ohm resistor. Then we applied high voltage nanosecond pulses of known amplitude from the 50 Ohm cable based generator to the discharge system and registered voltage and current calibration signals.

By computer processing of the voltage and current oscillograms we calculated the input power P(t) and energy dissipation W in the discharge cell during one impulse as follows:

$$P(t) = U(t) \cdot I(t), \qquad W(t) = \int_0^t P(T)dT.$$

We had an opportunity to register relative spectral distribution of discharge radiation in the 200-500 nm range as well as temporal dynamics of spectral line intensities during discharge pulse. The optical system included diaphragms, aluminium mirror, monochromator, and photomultiplier tube (see fig.1). The signals from the PMT might be registered directly by oscilloscope (band 250 MHz) or by the microvoltmeter with integration circuit (τ=0.1 c). The calibration procedure of the optical system was fulfilled using deuterium reference lamp.

Results and discussion

The first experiments were carried out in air, nitrogen and helium. We used both municipal drinking water and distilled water as dielectric fillings of the discharge chamber. The discharge in air was ignited at pressure values ranged from 10 Torr to 400 Torr at the applied voltage of 25 kV. In nitrogen and helium at the same voltage amplitude the upper limit of the pressure range was higher and achieved 500 - 600 Torr and > 760 Torr respectively. The homogeneity of the discharge plasma was evaluated visually through the side windows of the outer electrode. The discharge in air was homogeneous up to 200 Torr and a clear structure of microdischarges appeared with pressure increasing. In helium the discharge was homogeneous over full investigated pressure range 1-760 Torr and structure of the microdischarges was seen weakly at higher pressures.

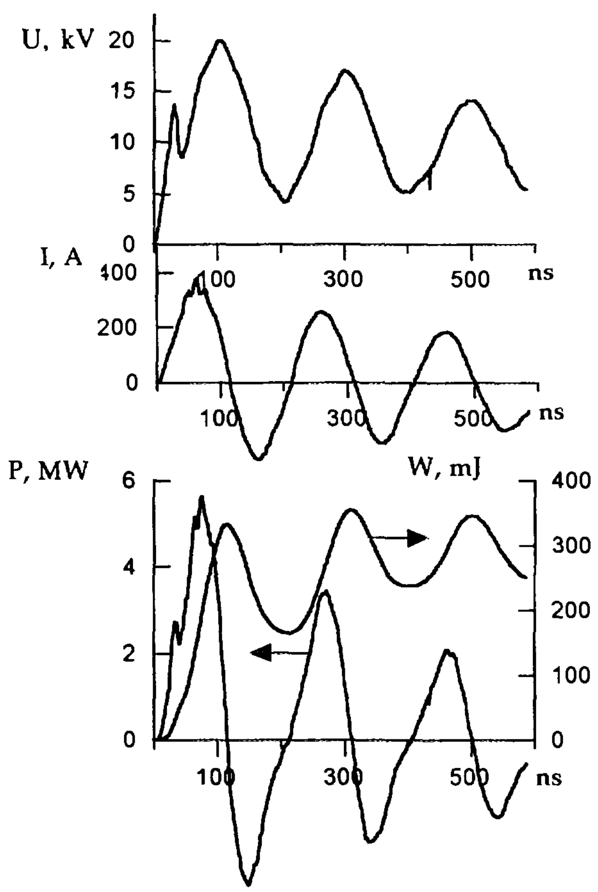

Fig.2 The electrical parameters of barrier discharge in helium. P=300 Torr, U0=25 kV.

On fig.2 the typical voltage U and current I oscillograms as well as calculated power P and energy W dissipation in the discharge circuit are shown. As it may be seen from fig.2 in helium there are strong oscillations of discharge current and voltage with duration up to 1000 ns. In air the behaviour of these parameters was the same but the duration of the oscillations was less than 200 ns.

The energy of impulse was dissipated in the discharge plasma and in dielectric barriers due to electric charge leakage. To register the energy leakage the measurement of energy dissipation W0 in evacuated discharge cell without discharge in it was fulfilled. The value W0 was 50 mJ and we took it in consideration to calculate the energy dissipation in the discharge plasma.

It was found that W value did not depend on pressure, the gas filled the cell and the repetitive frequency of supplied voltage pulses. There is a dependence of W on the amplitude of voltage impulse. Increasing of the applied voltage from the 23 kV to 30 kV lead to the increase of energy dissipation from 200 mJ/pulse to 500 mJ/pulse. Taking into consideration that the repetitive frequency of nanosecond generator was 600 Hz and 1200 Hz the average input power and power density in the discharge cell was 120-600 W and up to 230 mW/cm^3 respectively.

We registered the relative spectral distribution of discharge radiation in air, nitrogen and helium. The obtained spectra showed that there was not considerable contamination of the discharge cell during discharge operation.

Conclusion

The experimental investigations of the characteristics of barrier discharge in air, nitrogen and helium driven by high voltage pulses with nanosecond rise time were fulfilled. The discharge was homogenous over wide gas pressure range. The power density of up to 250 mW/cm^3 in the discharge plasma was obtained.

References

1. Kogelschatz U., Journal of Applied Surface Science, V.54, 1992, p. 410-423.
2. Visir V.A. and others. Russian Journal of Quantum Electronics, V22, N5, 1995.