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FORMATION STAGES OF PULSED DISCHARGE IN OXYGEN AND CARBON TETRAFLUORIDE

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This paper reports the current and voltage oscilloscope waveforms of a pulsed discharge measured in a broad range of frequencies (from 20 to 300 kHz) and duty cycle from 0.15 to 0.85 for two values of oxygen and carbon tetrafluoride pressure values of 0.1 and 1 Torr. Current oscilloscope waveforms of the glow pulsed discharge have been found to possess a plasma phase and an afterglow phase. The following stages of the plasma phase have been observed: 1. The capacitive current pulse of about 0.5–1 μs in duration; 2. The current growth stage the duration of which depends on the gas species, the plasma phase duration and the pressure; 3. The plateau (remarkably pronounced only for carbon tetrafluoride and absent for other gases); 4. The current decrease of tens microseconds in duration down to the level corresponding to that of the direct voltage discharge.

Keywords: pulse discharge, current and voltage oscilloscope waveforms, discharge formation, plasma phase, afterglow.

ЭТАПЫ ФОРМИРОВАНИЯ ИМПУЛЬСНОГО РАЗРЯДА В КИСЛОРОДЕ И CF_4

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В данной работе были измерены осциллограммы тока и напряжения импульсного разряда в широком диапазоне частот (от 20 до 300 кГц), коэффициентов заполнения от 15 до 85 %, для двух значений давлений 0,1 и 1 Торр кислорода и CF_4. Было получено, что осциллограммы тока тлеющего импульсного разряда имеют плазменную фазу и фазу послесвечения. Наблюдались следующие этапы плазменной фазы: 1. Импульс емкостного тока длительностью примерно 0,5–1 мкс; 2. Этап роста тока, длительность которого зависела от сорта газа, длительности плазменной фазы и давления; 3. Плато (заметно выраженное лишь для CF_4 и отсутствующее в кислороде); 4. Уменьшение тока, длившееся десятки микросекунд, до уровня, соответствующего разряду с постоянным напряжением.

Ключевые слова: импульсный разряд, осциллограммы тока и напряжения, формирование разряда, плазменная фаза, послесвечение.

ЕТАПИ ФОРМУВАННЯ ІМПУЛЬСНОГО РОЗРЯДУ В КИСНІ І CF_4

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У цій роботі були виміряні осцилограми струму і напруги імпульсного розряду в широкому діапазоні частот (від 20 до 300 кГц), коефіцієнтів заповнення від 15 до 85 %, для двох значень тиску 0,1 і 1 Торр кисню і CF_4. Було отримано, що осцилограми струму тліючого імпульсного розряду мають плазмову фазу і фазу післясвітіння. Спостерігалися наступні етапи плазмової фази: 1. Імпульс ємнісного струму тривалістю приблизно 0,5–1 мкс; 2. Етап зростання струму, тривалість якого залежала від сорту газу, тривалості плазмової фази і тиску; 3. Плато (помітно виражене лише для CF4 і відсутнє в кисні); 4. Зменшення струму, що тривало десятки мікросекунд, до рівня, відповідного розряду з постійною напругою.

Ключові слова: імпульсний розряд, осцилограми струму і напруги, формування розряду, плазмова фаза, післясвітіння.

INTRODUCTION

Presently the ion-plasma technologies are firmly established in contemporary life. The production of displays, medical equipment, the materials modification, solar power industry cannot do without plasma technologies. Plasma technologies based on direct current gas discharges are the simplest ones, but in recent decades the radio frequency discharges have come to the front and become the main plasma tool for large-scale production of semiconductor devices. Conventionally different plasma sources possess very close parameters and plasma processing rates if the chamber design, the pressure, the gas content and the power consumed by the plasma are the same. Therefore there come to the forefront such applied aspects as the degree of efficiency, the reliability, the simplicity of control, the equipment cost. The rf systems are not perfect from this viewpoint: the high cost of rf generators, a sufficiently low efficiency factor, the need of an auxiliary system of tuning to a plasma load which is complicated in controlling. The pulsed discharge of intermediate frequency (tens-hundreds kHz) is a worthy alternative. The pulsed current in a gas is one of the most important ways of producing low temperature plasma. Contemporary circuit technology of microelectronics enables one to design medium-frequency sources of oscillations with a rectangular pulse applicable for plasma production in a wide power range (from some watts to hundreds kilowatts). Such sources possess a much higher efficiency factor, a lower cost and considerably simplified tuning to the plasma and controlling. Pulsed gas discharge devices are now widely applied in diverse branches of science and technology: as the sources of light, in lasers, electro-erosion machines, welding apparatuses, plasma display panels as well as under plasma nitriding, reactive magnetron depositing etc. Many devices operate now in a pulsed mode: plasma chemistry reactors, MHD transformers, plasma injectors and accelerators. But until now medium frequency discharges have been studied in a considerably lesser degree than radio frequency or direct current discharges, what hampers the progress in this area. Therefore the processes taking part in the formation and decay (afterglow) of the unipolar pulsed discharge of low pressure in different gases were an object of this study.

REVIEW OF PUBLISHED PAPERS ON PULSED DISCHARGES

In last decades the fundamental results obtained in the research of low temperature plasma have found wide application in the development of new methods and technologies of synthesizing nanostructure films required in various branches of industry. The scientists from the USA, Europe, China and other countries are occupied intensely with such problems [1]. Low temperature non-equilibrium plasma is broadly applied in many technological processes of etching semiconductor materials, depositing thin films, plasma thrusters, lighting devices, plasma display panels and many others [2, 3]. Conventionally plasma technologies employ the radio frequency capacitive discharges or the direct current discharges. These discharges have been studied sufficiently well [4, 5]. But now the non-equilibrium plasma in pulsed fields still remains much less studied.

In this section we consider the results of studies into the ignition and modes of burning of the discharges in pulsed fields.

The direct current pulsed discharge is also actively applied for surface processing, sputtering, producing films with improved parameters. Such a technique of discharge production possesses a number of advantages in comparison with a radio frequency or a glow discharge. In a glow discharge a spot of an arc discharge may form on the cathode because of large currents applied conventionally in diverse sputtering systems due to the redistribution of the space charge. Its appearance would lead to the cathode erosion as well as to the drop phase formation in deposited films. Periodic reversal (sign change) of the applied voltage may impede the formation of this space charge due to the opposite polarity voltage acting in the second half of the pulse. Such a technique is widely used to decrease or prevent the arc generation in the systems of reactive sputtering and it enables one to produce denser films with an enhanced transparency.

The book [6] e.g. is devoted to gas breakdown and pulsed discharge formation. It is pointed out in it that under pulsed gas breakdown a certain time lag is observed between the moment of the voltage application to the electrodes and the start of the breakdown called the delay time. This delay time is usually split into two parts: the statistical delay time during which an initiating electron appears within the gap and the formation time during which a breakdown develops due to the primary electron avalanche buildup and the subsequent stages of the ionization growth. The formation time amounts to about 10^{-8} sec, i. e. it is equal to the drift time of electrons within the gap to the order of magnitude.

At the first stage of the Townsend breakdown the current growth takes place due to the generation of electron avalanches following each other in time. The duration of this stage exceeds, naturally, the time of electron drift within the gap and it may take from hundreds nanoseconds to tens microseconds depending on the character of secondary processes and overvoltage. The transition from the avalanche generation stage to the next stage characterized by the propagation of ionization waves within the gap sets in due to the accumulation of space charge of positive ions near the anode enhancing the field outside the space charge zone. About 500 nsec after the discharge initiation an intense glow appears near the anode, its front propagating to the cathode. When it touches the cathode a front of the ionization wave forms directed from the cathode to the anode. The ionization wave propagation makes the distribution of plasma concentration equal along the gap width and a column of the quasi-neutral glow discharge and a region of the near-cathode potential drop are formed. Thus the discharge experiences a transition to the following phase — the phase of volume burning.

The authors of book [6] present the oscilloscope waveforms of the voltage and current for the 600 nsec rectangular voltage pulse of 4 kV in amplitude applied to the point electrode at the distance of 1.5 mm from the water surface (serving as the grounded electrode) at the atmospheric gas pressure. The frequency of the pulsed discharge was 6 kHz. From this figure one observes that during the voltage pulse a discharge formation takes place that is accompanied by the linear current growth. Current jumps are observed for the abrupt voltage increase as well as for its switching off associated with the capacitive current appearance.

Efimova in her thesis [7] has studied the formation of the pulsed discharge in argon and nitrogen in the pressure range from 2 to 7 Torr (3–9 GPa) with the duty cycle from 0.1 to 0.4 and the pulse duration of the voltage applied from 10 to 4000 μs. She has found that on growing the voltage the discharge current increases and at the early stages of the discharge development this current is considerably larger than one got by the application of a constant voltage.

It has been revealed that the current signal is not constant during the pulse with its duration being an important parameter. Experimental data have demonstrated that with the duty cycle fixed the average discharge current depends on the pulse duration. The shorter is the pulse duration the higher is the average current.

Besides, Efimova has presented the CVCs of the discharge constituting the dependence of the average current (over a pulse) against the voltage applied. It follows from this figure that with the pulse duration fixed (200 μs) the current during the pulse depends strongly on the duty cycle. Decreasing the fill factor leads to the increase of the average discharge current.

The authors of a number of papers [8–11] have made numerical studies of the processes taking place under the breakdown of the dc pulsed discharge at low nitrogen pressure in a «point-to-plane» design. They have obtained the temporal dependencies of the current, the potential and the particle concentration as well as explained the cathode sheath formation.

The authors of paper [8] have presented the temporal dependence of the discharge current for the nitrogen pressure of 4 Torr and the applied voltage of 1.2 kV and they have split the formation stage of the pulsed glow discharge into 3 consequent parts. During the first part the gap is slowly filled with the ions produced near the anode, then during the second part the ionization front is formed near the anode propagating to the cathode. Now the cathode sheath develops and the participation of secondary effects begins leading to the third part, i.e. to the glow discharge formation.

Also the authors of papers [8–11] have studied the effect of pulsed discharge parameters in the mixtures of nitrogen, oxygen and argon on the variation of polymer films wetting. When a negative voltage pulse is applied to the cathode then the charged and excited particles are produced during a period of film processing by the glow discharge. Between two consequent pulses an afterglow of the decaying plasma is observed. As a result, a polymer surface is processed in the plasma phase by the reactive particles produced under the discharge current flow as well as during the afterglow phase by the particles with a large effective lifetime. When the magnitude of the negative potential pulse applied to the lower electrode is above the breakdown potential, the neutral gas (nitrogen) is ionized and a pulse of current $I(t)$ is observed with the increment time of 100 nsec and the decay time of 5 μsec. The measured CVCs obtained for different pressure values in the pulsed mode of the DC discharge correspond to the start of the abnormal glow discharge. One observes from the data outlined in papers [8–11] that the discharge current increases with the growth of the pulsed voltage applied the gas pressure being constant. Besides, as the duration of the plasma phase and the afterglow time are inversely proportional to the frequency of the applied voltage, then it is obvious that the remaining active particles (molecules) being left from the preceding plasma phase may initiate the next plasma phase (making the gas breakdown easier) when the frequency increases.

It is worth remarking that one may observe in the oscilloscope waveforms obtained in papers [8–11] that during the plasma phase the discharge current tends to approach some constant value. At low values of the voltage applied across the gap the current increases gradually during the pulse time whereas at high voltage values, on the contrary, the current oscilloscope waveform lowers a little.

Paper [12] has studied in experiment and modeling a pulsed discharge of low pressure in the mixture of helium with the 2 % xenon. In order to study the temporal dependence of the pulsed He-Xe discharge a self-sustained model has been employed consisting of the Boltzmann equation with the temporal dependence for determining the kinetic properties of electrons, the set of equations for the velocity of the respective heavy particles in the cylindrical, axially symmetric discharge system and the set of equations for the external electric circuit. The authors of paper [12] have presented the data of calculations and measurements of periodic variations of the discharge current and voltage at the pressure of 2.5 Torr and different applied voltage values. The discharge evolution encompasses the time period from 0 to 1 msec. It may be separated into four different stages: the ignition one and the basic one during the plasma phase of the pulse as well as the switching off and the afterglow when the voltage is absent across the electrodes. At the start of the ignition phase from $t = 0$ a fast increase of the discharge voltage gives rise to the continuous growth of the current. When the current density exceeds about 10 mAcm^{-2}, a drop of the voltage is observed. The voltage is decreasing to the extent when the current approaches its maximum value. The average duration of this phase varies from 20 to 100 μsec depending on the initial conditions. During the basic phase of the discharge the voltage remains almost constant, and the current is decreasing uniformly as a result of the dominant loss of electrons due to ambipolar diffusion to the walls. At the moment of $t = 500$ μs the generator voltage is switched off during 200 nsec. The next afterglow phase persists for about 500 μs.

In technological processes one applies not only a dc pulsed discharge but also the pulses (packets) of the RF voltage with which an inductive discharge is produced. For example, the authors of paper [13] report on the technique of producing C_nH_m-fragments with a pulsed inductive discharge of different frequency and duty cycle values. They have demonstrated how one may control the plasma characteristics and the concentration of carbon-hydrogen clusters of various C:H content applying the appropriately chosen durations of the plasma and afterglow phases.

The kinetics of CF and CF_2 radicals (in their main electronic states) has been studied by the authors of paper [14] with the laser-induced fluorescence (LIF) in the inductive discharge in CF_4 at the pressure of 33 mTorr in a steady state as well as in the pulsed mode. Large attention has been paid to the behavior of the radicals listed above not only in the burning discharge but also in the afterglow of the pulsed discharge. They have demonstrated that the concentration of CF_2 radicals increases considerably (more than 4 times compared with the steady state) at the start of the afterglow that may be associated with the gas-phase reactions producing CF_2.

In paper [15] its authors have presented the data on the temporal behavior of the electron distribution function over energy (EEDF), measured with the Langmuir probe in the discharge tube during the afterglow phase of the pulsed inductive discharge. They have demonstrated that the electron loss to the tube walls is the main mechanism of energy loss for EEDF. Free fast electrons with the energy exceeding the wall potential barrier quickly leave the ambipolar potential well of the plasma volume to the tube walls, and «cold» trapped electrons are kept in the plasma thus leading to their diffusion cooling in the process of the afterglow.

The book [16] reports the results of studies into the development of the weakly ionized plasma in argon produced by the pulse of the solenoidal rf field. The experiments have been performed at the pressure values from 0.02 to 1 Torr. During the total pulse duration of 2200 μs they have measured the temporal dependencies of the longitudinal magnetic field, the probe current, and the spectral lines intensity. They have established that the plasma glow starts in the peripheral ring near the tube walls and then it propagates to the axis filling the total tube cross section. It is related to the appearance of excited particles in the places with the largest value of the tangential electric field. For the argon pressure of 1 Torr and the electron temperature from 1 to 10 eV it has been found that the characteristic EEDF relaxation time amounts to 10 μs.

The oscillatory excitation and decay of the B-state of nitrogen molecules has been studied by the authors of paper [17]. They have studied how the pulsation frequency and the duty cycle affect the oscillatory distribution of nitrogen molecules obtained from the spectrum of the first positive system at different duration periods of the plasma and afterglow phases in the pressure range 2.4 mTorr–1.5 Torr. They have demonstrated that increasing the plasma phase duration from 0.1 to 5 msec leads to the retardation of the decay rates of the excited B-states of nitrogen molecules. It is probably associated with the accumulation of the metastable and oscillatory-excited nitrogen molecules during the plasma phase.

DESCRIPTION OF THE EXPERIMENTAL DEVICE

The experiments reported in this paper have been performed with the device the setup being shown in Figure 1. The flat stainless anode and cathode are placed inside a discharge tube of 56 mm inner diameter with the inter-electrode distance kept unchanged in all experiments at 20 mm. The cathode is fed with a pulsed monopolar negative potential from the generator in the 20–300 kHz frequency range, with the duty cycle values from 0.15 to 0.85 and the applied voltage values up to 1000 V. The anode potential was zero. The inter-electrode voltage and the discharge current have been registered with the PCS500 oscilloscope (Velleman Instruments), with its fed to the personal computer. The range of the discharge current values registered did not exceed 100 mA.

Two gases with different characteristics have been chosen for the experiments. Both gases were electronegative, and negative ions were formed during the discharge burning. The first of them and the least electronegative one was oxygen, the degree of electronegativity for it $\alpha = n_-/n_e$ (n_- and n_e are the concentrations of negative ions and electrons, respectively) usually was in the range 1–10 [18–23]. The carbon tetra fluorine possesses a higher degree of electronegativity amounting to α = 10–100 [18, 24–26]. All experiments have been performed for two values of the gas pressure, i.e. 0.1 Torr and 1 Torr. The gas pressure has been registered with the capacitive pressure probes of the baratron type with the maximum measured values of 10 Torr and 1000 Torr.

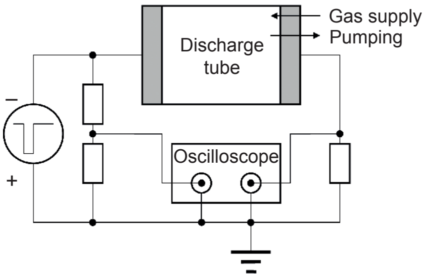

Fig.1. The setup of the experimental device

EXPERIMENTAL RESULTS

For the research into the properties of the pulsed discharge the voltage and current oscilloscope waveforms have been studied presented e. g. in Fig. 2. The cathode was fed periodically with the negative potential of the amplitude *U*. In what follows we will denote the pulse duration with the letter *T*, and the quantity inverse to the period (frequency) with the letter *f*, whereas the ratio of the pulse duration to its period (the fill factor) with the letter *D* (from the English term *duty cycle*). The figure demonstrates two different phases: a plasma phase (when a negative voltage is fed to the electrode) and an afterglow phase (there is no voltage across the electrodes, the plasma is decaying in an afterglow).

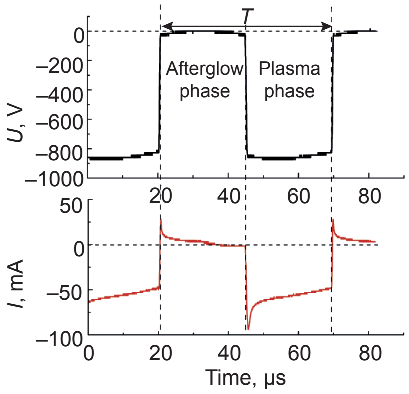

Fig. 2. Waveforms of the applied voltage and the obtained discharge current in CF_4 for the pressure of 0.1 Torr, the duty cycle of 0.5 and the frequency of 20 kHz

The oscilloscope waveforms are typical ones depicting the well expressed both phases. The shape of the current pulse differs from a rectangular one. First of all we note the presence of abrupt current jumps at the start of each phase i.e. on changing the voltage. During switching on (the plasma phase) the voltage decreases abruptly during 0.5 μs down to the value of –900 V, what is accompanied by the negative current jump down almost to –100 mA with its subsequent decrease. When the voltage is taken off the electrodes a current jump also appears but to the positive side up to the value of about 25 mA. This surge is the displacement current because under the discharge ignition the voltage experiences an abrupt change which is accompanied by the onset of the displacement current jump the magnitude of which is proportional to the voltage change. Therefore one cannot regard the current surge during the voltage switching on and off as a current of charged particles.

The oscilloscope waveforms have been measured for the two gases at the pressure values of 0.1 and 1 Torr. An attention has been paid to the shape of the current oscilloscope waveforms during the plasma phase as well as during the afterglow one. For the same gases the current values have been measured for these gases in the dc glow discharge for different pressure values. For CF_4 the CVCs have been also taken for different duty cycle and frequency values.

Consider the plasma phase of the pulsed discharge burning at different gas pressure values and other parameters.

Pulsed discharge in oxygen

Figure 3 presents the oscilloscope waveforms measured for the pulsed discharge with the oxygen pressure of 0.1 Torr. As it has been already said above, at the start of the plasma phase an abrupt growth of the current takes place with the increase of voltage, which is actually a jump of the displacement current with about 0.5 μs duration. After that the discharge current starts growing what is probably associated with the charged particles having remained after the preceding plasma phase. They have filled the cathode and anode sheaths during the afterglow phase and escaped to the electrodes at the moment of the discharge ignition. The discharge current growth occurs during about 0.2 μs. The third stage of the current decrease has a duration of tens microsecond, when the discharge current approaches the constant value of 9.7 mA. As was the situation in the preceding cases, the plasma phase time is insufficient to achieve the current value associated with the constant voltage.

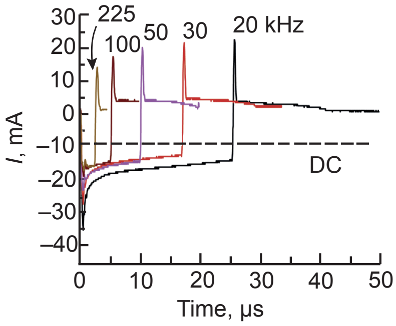

Fig. 3. Discharge current oscilloscope waveforms with the maximum pulsed voltage of 700 V, the duty cycle of 0.5 and the pressure of 0.1 Torr in oxygen

Figures 4 and 5 depict the oscilloscope waveforms for the pulsed discharge in oxygen at the pressure of 1 Torr and the supported voltage of 400 V. It is clear from the figures that for the discharges with a prolonged plasma phase (low frequency) the exterior shape of the current oscilloscope waveform resembles that in other gases at the pressure of 0.1 Torr. Portions of the waveforms associated with the discharge formation coincide with the portions we determined for the discharge in nitrogen. After the peak of the capacitive current (range I in Figure 5) an increase of the discharge current occurs during 0.2 μs (range II), the current passes through the maximum and then it decreases (range III). But for the discharges possessing the plasma phase duration less than about 6.7 μs, after the first stage one observes the current decrease to the value –(30–40) mA during the time less than 1 μs. For the discharge with the plasma phase duration of 5.7 μs the phase of the current increase is limited with a plateau region of the discharge current with the duration of about 1 μs. The shape of the discharge current within this range of the plasma phase duration is similar to the oscilloscope waveform of the current for other gases at the pressure of 1 Torr.

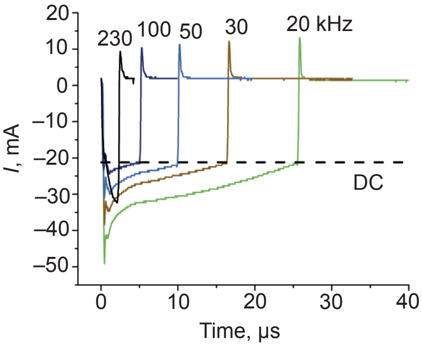

Fig. 4. Discharge current oscilloscope waveforms at the maximum pulsed voltage of 400 V, the duty cycle of 0.5 and the pressure of 1 Torr in oxygen

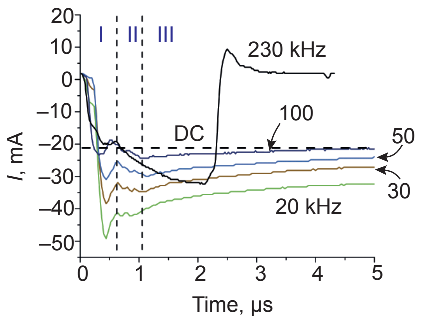

Fig. 5. Plasma formation stages considered taking the discharge in oxygen as an example with the pressure of 1 Torr, the duty cycle of 0.5 and the applied voltage of 400 V

Pulsed discharge in carbon tetrafluoride

Now let us consider the results obtained for carbon tetrafluoride. Figure 6 presents the oscilloscope waveforms of the discharge current we have measured for the CF_4 pressure of 0.1 Torr, the duty cycle of 0.5, the applied pulsed voltage of 700 V within the frequency range from 20 to 180 kHz. We observe in the presented figure that the current decreases considerably compared to one at the first microseconds of the discharge for the discharges with a prolonged plasma phase (lower frequencies). For higher frequencies and, consequently, shorter times of plasma phase burning the current decreases insignificantly. It is worth remarking that in a shorter plasma phase the current during the first microseconds (just after the capacitive surge) is also much lower than at low frequencies during the time range II in Figure 7 (in which the first 5 μs of the discharge burning are presented).

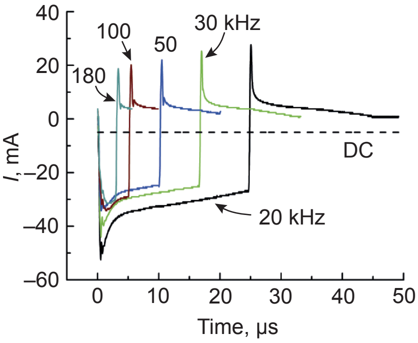

Fig. 6. Discharge current oscilloscope waveforms at the maximum pulsed voltage of 700 V, the duty cycle of 0.5 and the pressure of 0.1 Torr in CF_4

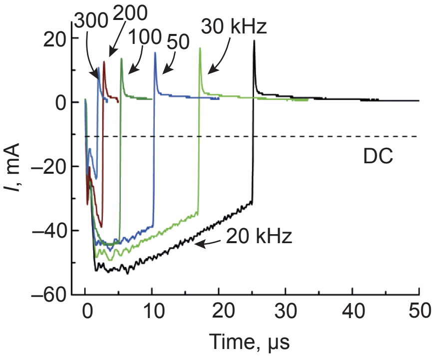

Fig. 7. Discharge current oscilloscope waveforms for the maximum pulsed voltage of 488 V, the duty cycle of 0.5 and the pressure of 1 Torr in CF_4

Current and voltage oscilloscope waveforms of the pulsed glow discharge for the carbon tetrafluoride pressure of 1 Torr, the duty cycle 0.5, the voltage of 488 V and the frequencies in the range from 20 to 300 kHz are presented in Fig. 8. One may also note that the plasma phase possesses several stages.

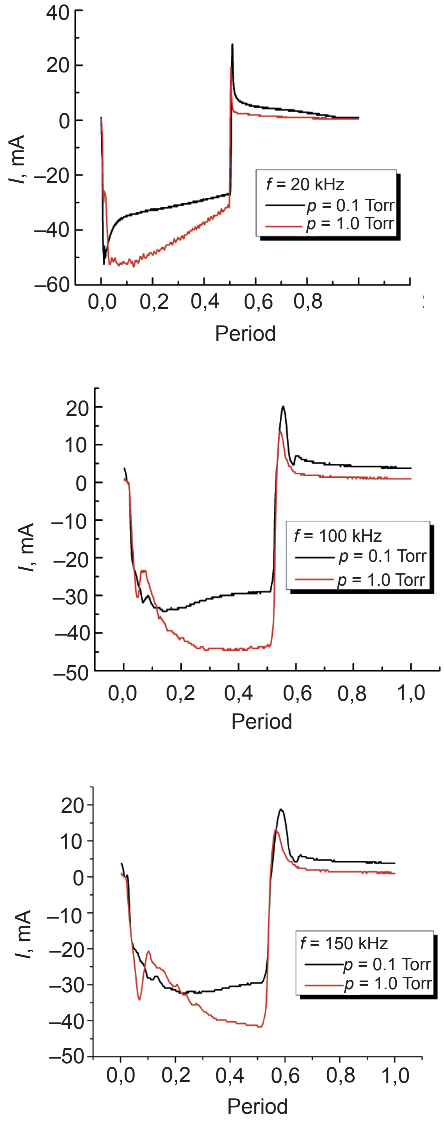

Fig. 8. Comparing the discharge current oscilloscope waveforms for the CF4 pressure values of 0.1 (700 V) and 1 Torr (488 V) with the duty cycle of 0.5

I. The capacitive current surge,
II. The current growth,
III. The well expressed plateau,
IV. The current drop.

Consider each of the stages separately.

I. The capacitive current surge.

The pulse duration of the capacitive current is practically the same for all gases and it amounts about to 0.5 µs. In this case this pulse approaches 35 mA.

II. The current growth.

The duration of this stage amounts about to 1–1.5 µs. The current growth stage for CF$_4$ is available not only for the pressure of 0.1 Torr but also for the case of 1 Torr now under consideration. For the discharge with the longest plasma phase of 25 µs the current growth starts from the values about –25 mA and it finishes at the level of –50 mA.

III. The plateau.

At the plateau stage the discharge current approaches a certain constant value. For the longest pulse at the frequency of 20 kHz this value is –50 mA. For the discharges with the shorter plasma phase the plateau level is in the limits –(40–50) mA. The duration of this regime is about 4 µs.

IV. The current drop.

The stage of the current drop continues until the current stabilizes and approaches the level marked with a horizontal broken straight line. This stage may persist for hundreds microseconds, but we have not fixed the moment of saturation because our generator has not been capable of operating in this frequency range. We have observed only the current drop and the approach to its constant value.

It is worth noting that regardless of the plasma phase duration fixed by establishing the frequency and the duty cycle the discharge undergoes a number of formation stages it has time to undergo during the time period it is allowed to occur.

Let us now compare the oscilloscope waveforms of the discharge current at CF4 pressure values of 0.1 and 1 Torr with the same duty cycle of 0.5 during a single period of the pulse for the frequency values of 20 kHz, 100 kHz and 150 kHz (see Fig. 9). From this figure one may draw the conclusion that on growing the gas pressure the growth period of the discharge current also increases. For example, for the frequency of 20 kHz at the pressure of 0.1 Torr the time required for the discharge current to approach its maximum value amounts to about 1 µs and at 1 Torr it increases to 2 µs and then it approaches a plateau. During the remaining part of the plasma phase the discharge current decreases uniformly. For the frequency of 100 kHz the discharge current at the pressure of 0.1 Torr approaches its maximum and then it decreases partially whereas as at 1 Torr it has only time to approach a plateau. For a still larger frequency of 150 kHz and the gas pressure of 1 Torr the oscilloscope waveform for the discharge plasma phase consists almost totally of the growing portion of the current.

CONCLUSIONS

This paper has studied the current and voltage oscilloscope waveforms of the pulsed discharge in oxygen and carbon tetrafluoride within the frequency range from 20 to 300 kHz, the duty cycle from 0.15 to 0.85 for two pressure values of 0.1 and 1 Torr. It has been demonstrated that the current oscilloscope waveforms of the glow pulsed discharge in these gases possess a plasma phase and an afterglow phase.

During the formation processes the plasma phase is going through the following stages: 1. The capacitive pulse current stage of about 0.5–1 μs in duration; 2. The current growth stage which duration depended on the gas species, the plasma phase duration and the pressure; 3. The plateau stage which was remarkably expressed only for CF_4, and it was absent in oxygen; 4. Current decrease stage of tens microseconds in duration down to the level corresponding to the direct voltage discharge.

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