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PLASMA NEW SELECTIVE PROPERTIES FOR EFFICIENT USE IN ELECTRONICS AND TELECOMMUNICATIONS

Abstract. In terms of active and passive electronic counteraction, detection of geophysical phenomena of artificial and natural origin is becoming increasingly important. Discovering new properties of plasma enables to improve the information component of radio signals more effectively and use the obtained properties in related fields. Elementary processes in the longitudinal and transverse directions of the discharge, depending on natural and artificial conditions, under different types of gaseous medium used; at different gas pressures and different pulse-periodic application of an electric field is studied in the article. The difference of discharge properties in inert and molecular gases with different designs and electrodes of the laboratory device is shown. It is established that the change of functional purpose between the cathodes and the anodes does not change the shape of the discharge. The presence of ambipolar diffusion of charge carriers acting on a large area of plasma was determined. Partial charge carrier homogeneity has been established, which is observed only along the plasma surface, and homogeneity is violated in the perpendicular direction. The difference in energy input in the discharge, depending on the design of the electrodes other things being equal is determined. The identified properties of plasma enable them to be used more effectively for practical implementation in the field of electronics and telecommunications and other industries.

Keywords: electronics and telecommunications; ionospheric perturbations; technological plasma; volt-ampere characteristics; complicated conditions; space charge; localized discharge.

Introduction

Recently, traditional methods and ways of obtaining information are closed to the limits of their capabilities. In this regard, more and more attention is paid to finding new sources of information and ways to obtain it [1]. In the terms of active counteraction to all types of exploration, detection of geophysical phenomena of artificial and natural origin has recently become more and more relevant in the world. Such phenomena include ionospheric perturbations, which occur under the influence of factors of both natural and artificial origin [1, 2].

By discovering new properties of plasma, it enables to improve the information component of radio signals more effectively [3]. Obtaining new selective properties of technological plasma, will enable its usage in related fields designed to improve human life, for example, for plasma chemical water treatment, for spraying thin films in industry, for disinfection of fabrics and surfaces in medicine, for neutralization and disposal of industrial sludges. [4, 5].

Plasma is called low-temperature if its average electron energy is less than the characteristic ionization potential of an atom (<10 eV); its temperature usually does not exceed 105 K. Technological low-temperature plasma is weakly ionized, ie, the number of neutral atoms and molecules significantly exceeds the number of charged particles - electrons and ions [6]. Since the Coulomb interaction between charged particles is much stronger than the interaction between neutral particles, and this interaction is long-range, the presence of charged particles in a low-temperature plasma largely determines its properties, including electrical and electromagnetic. Many types of low-temperature plasma exist in nature [6, 7], they create low-temperature technological plasma in various laboratory and production systems [6, 8].

Low-temperature plasma is produced using various types of electrical discharges or electron beams. In this case, the bulk of the electrical energy goes to the production of energetic electrons, and not to heat the gas stream. The interaction of these electrons with the working gas and the surface of the electrodes leads to the creation of excited states of atoms and molecules, free radicals, ions and additional electrons for the ionization set [5].

However, the known literature does not fully address the issues of practical implementation of the selective properties of plasma.

For the proper use of low-temperature plasma in technological processes, it is necessary to understand the basic principles of the discharge in order to control the plasma parameters.

The purpose of the article is to analyze and identify the features of volt-ampere characteristics of plasma, depending on the physicochemical properties of the materials used and the energy parameters of the discharge, for practical implementation in telecommunications and other industries.

Basic material and results

The existence of a discharge with a total radiation plasma in a localized device is limited by the gas pressure (which fills the discharge volume), the combustion voltage and the manufacturing technology. This pressure limitation is manifested in the fact that with increasing gas pressure complicated conditions are not met. In this case, there are no conditions for the formation of localized plasma. As the gas pressure decreases, this plasma can be formed up to 0.133 Pa or less. But under this condition it is necessary to greatly increase the combustion voltage. Under conditions of a certain small pressure, the combustion voltage is so high that the voltage source does not provide combustion of the discharge.

Another factor limiting the formation of this plasma is the design and technological difficulties. The manufacture of gas discharge devices such as localized, small diameter and with a large number of electrodes is very difficult due to the complexity of technology, assembly and glass blowing. As a result, these devices are not manufactured with a diameter of less than 8 mm [9].

Depending on the type of gas, the restrictions on the formation of localized plasma have different limits of pressure, voltage, diameter and number of electrodes in the device.

For example, in an inert argon gas, a total radiation plasma was formed in a device with a diameter of 46 mm and 20 electrodes; the highest pressure limit value during the study of this discharge was 535.95 Pa, at an anode voltage of U =188 V, and discharge current $8{,}1 \cdot 10^{-2}$ A. At a minimum pressure $p = 3{,}47$ of Pa, the maximum combustion voltage was 690 V, and the discharge current $1{,}3 \cdot 10^{-3}$ A.

The measured parameters of the discharges with the plasma of the total radiation are given in Table 1 for neon, air, hydrogen, combustible gas (propane) C_3H_8, carbon dioxide and nitrogen in a device with 20 electrodes, with a diameter of the discharge gap D= 46 mm.

Table 1 – **Discharge parameters depending on the type of gas, voltage and discharge current**

№ ch.	gas	p, torus	U, V	$I \cdot 10^{-3}$, A
1	Argon	4,02 - 0,026	190 - 690	81 - 1,3
2	Helium	5,14 - 0,04	185 - 760	58 - 1,7
3	Neon	1,7 - 0,08	210 - 730	36 - 1,5
4	Air	3,26 - 0,09	560 - 980	71 - 2,4
5	Hydrogen	3,8 - 0,12	540 - 1020	25 - 3,1
6	Propan C_3H_8	3,4 - 0,16	550 - 960	110 - 1,4
7	Carbon dioxide CO_2	4,9 - 0,06	610 - 1220	94 - 1,7
8	Nitrogen	6,21 - 0,11	510 - 870	133 - 2,1

Table 1 shows that the discharges with the total radiation plasma in inert gases exist at lower stresses than in the atmosphere of heavy molecular gases, and there is a difference in the pressure limits.

For molecular gases, these values are slightly higher. Under the condition of a constant diameter of the discharge interval, the increase in the number of rod electrodes N shifts the limitations on the formation of this plasma in the direction of high pressures.

The boundaries of the existence of the plasma of the total radiation, depending on the diameter of the discharge gap, are presented in Table 2.

The discharge in the localized device is a typical case of electric current in the gas. Unlike a discharge with plane-parallel intervals, the discharge in this device does not have a variety of discharge zones. In the longitudinal and transverse directions of the discharge, there is only one illuminated area - negative radiation and one dark space, which is located between the electrodes and the radiation.

Table 2 – **The boundaries of the total radiation existence of plasma depending on the diameter of the discharge gap**

№ ch.	p, torus	N – number of electrodes	$2R \cdot 10^{-3}$, m
1	1,0	16	27,0
2	1,5	16	18,0
3	2,0	16	13,5
4	2,5	16	10,6
5	4,0	16	6,7

For all these pressures and test gases in this category there are no other zones. Changing the functional purpose between the cathodes and anodes does not change the shape of the discharge.

Measured volt-ampere characteristics of the discharge, for example, in argon is in a relatively small range of pressures 2.67 - 79.8 Pa (Fig. 1).

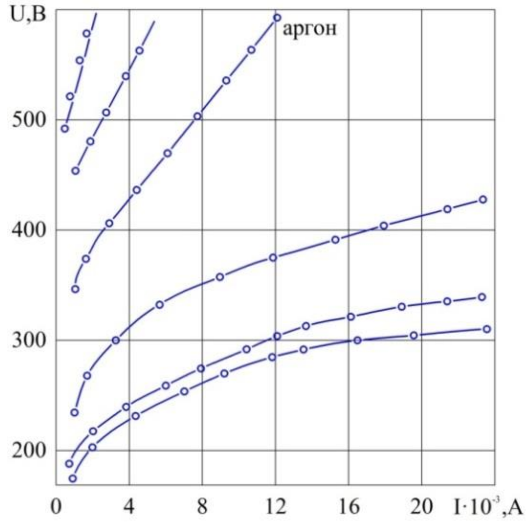

Fig. 1. Volt-ampere characteristics of the localized discharge, under conditions of changes in argon pressure: 1 – p =2.66 Pa; 2 – p =5.32 Pa; 3 – p = 7.98 Pa; 4 – p =13.3 Pa; 5 – p =53.2 Pa; 6 – p =79.8 Pa

However, despite the small pressure interval, the measured dependences $I = f(U)$ are significantly scattered in voltage and discharge current.

In the range of 2.67 - 79.99 Pa, they are in the range of 700 - 1000 V with a discharge current up to$8 \cdot 10^{-3} A$. When the pressure varies between 79.99 - 186.65 Pa, the characteristics are shifted to a range of relatively low voltages of 180 - 660 V, and the discharge current reaches 0.005 - 0.018 A.

With the change in pressure in the device, the discharge in the neon atmosphere has approximately the same arrangement of volt-ampere characteristics (Fig. 2).

In neon, as in argon, under conditions of low pressures, the dependences $I = f(U)$ lie in the region of high voltages and are mostly rectilinear. This indicates that a small space charge is formed in the dark space.

With increasing pressure in these inert gases, the volt-ampere characteristics become increasing, which is due to an increase in the space charge in dark space. Characteristically, despite the complication of conditions in the localized device, the discharge at low currents burns at relatively low voltages of 250 - 300 V. This voltage in the discharge is close to the tabular voltage of a short normal discharge, with plane-parallel intervals.

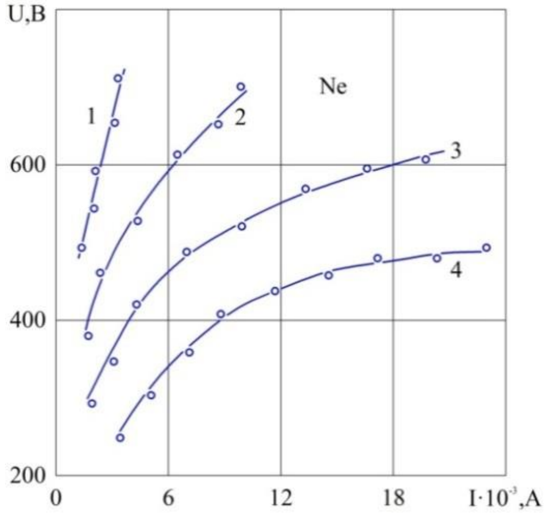

Fig. 2. Volt-ampere characteristics of the localized discharge under conditions of pressure change of neon: 1 – p =6,78 Pa; 2 – p = 11.97 Pa; 3 – p =25.27 Pa; 4 – p = 34.58 Pa

Plasma of total radiation is formed in the same way and in discharges with molecular gases. In the case of a discharge in an atmosphere of ordinary air, hydrogen, combustible gasC_3H_8, carbon dioxide, nitrogen, each time a column of plasma radiation of the general glow with a characteristic color due to the type of gas was created.

In contrast to inert gases, the volt-ampere characteristics in molecular gases lie in the region of higher voltage (Fig. 3, 4) and in a slightly larger pressure range. All the characteristics shown in Fig. 1 - 4, have a monotonic dependence and show that in all gases and at all specified pressures the discharge with the plasma of the general radiation is in the anomalous mode.

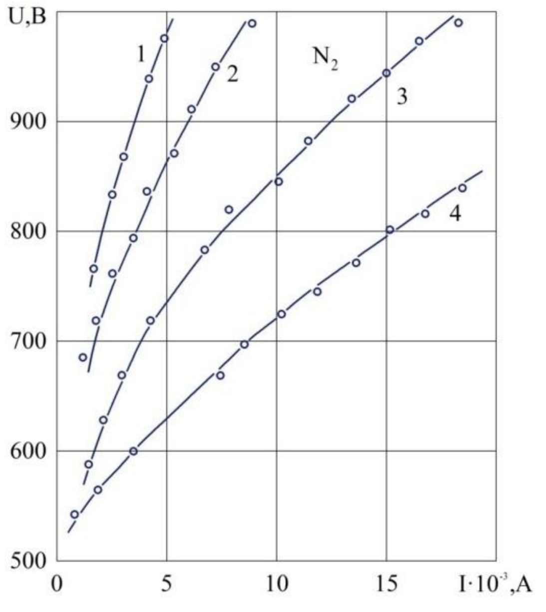

Fig. 3. Volt-ampere characteristics of the localized discharge, under terms of changes in nitrogen pressure: 1 – p =10.64 Pa; 2 – p =14.36 Pa; 3 – p =27.93 Pa; 4 – p =37.24 Pa

The upper pressure limits for the molecular gases studied differ insignificantly.

Molecular gases are characterized by a small change in the slope of the characteristics with increasing pressure. In this case, the convexity of these characteristics is not very pronounced. This indicates a slow increase in charge in a dark space as the anode voltage increases. Note that during the observation through the end window, the diameter of the column of plasma of the total radiation is larger than during the discharge in inert gases.

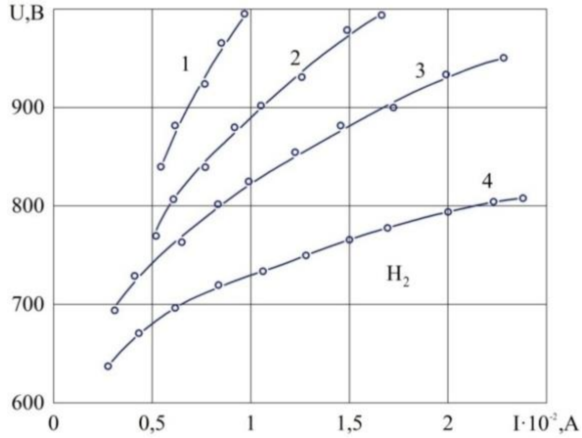

Fig. 4. Volt-ampere characteristics of the localized discharge, under terms of changes in hydrogen pressure: 1 – p =18.62 Pa; 2 – p =25.27 Pa; 3 – p =39.91 Pa; 4 – p =53.27 Pa

In the area of low pressures, where the required anode voltage was much higher - 1200 V, measurements were not performed.

In Fig. 5 compares the volt-ampere characteristics of a localized discharge and a flushing discharge with a plane-parallel gap under conditions of the same cathode area, energy input and helium pressure.

This comparison clearly displays that the dependence $I = f(U)$ of the discharge with a plane-parallel gap is located in the region of higher voltages, at low discharge currents.

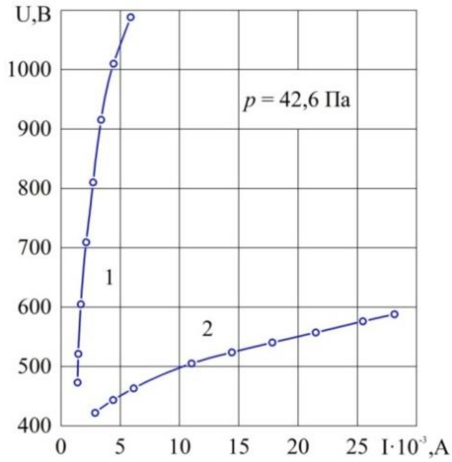

Fig. 5. Comparison of volt-ampere characteristics of the localized discharge - 2 and the discharge with a plane-parallel gap - 1; under terms of the same area of the cathode, energy input and helium pressure

Such a dependence of the localized discharge, on the contrary, is located in the region of much lower voltages at relatively large discharge currents.

From the comparison of volt-ampere characteristics, it was obtained that the localized discharge is more than 30 times higher than the flat gap discharge.

Such a large difference in is mainly due to the fact that in the localized discharge there is no ambipolar diffusion of charge carriers to the inner walls of the discharge chamber, and to the intense total emission of charge carriers formed on the entire cylindrical surface of the localized plasma.

Conclusions

The selective properties of low-temperature plasma in the discharge range, which have a significant difference from the known characteristics:

First, there is an excess of fast electrons in the plasma; the average energy of the main electrons is higher and is 2-3 eV, and the electron density is almost similar.

Secondly, the total emission of charge carriers occurs with a larger, but not with the entire surface of the plasma. The opposite surface of the plasma is not covered by these processes.

Third, there is ambipolar diffusion of charge carriers, which acts on a large area of plasma.

Fourth, there is only partial homogeneity in this plasma, which is observed only along the surface of the plasma, and in the perpendicular direction the homogeneity is violated.

The result of such differences is that the energy contribution in this category is higher than in the localized, under equal operation terms.

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Нові селективні властивості плазми для ефективного використання в електроніці та телекомунікаціях

О. В. Шефер, В. С. Марченко, Г. П. Чернева

Анотація. В умовах активної та пасивної радіоелектронної протидії, виявлення геофізичних явищ штучного і природного походження набувають все більшої актуальності. Виявлення нових властивостей плазми, дає змогу більш ефективно покращувати інформаційну складову радіосигналів та використовувати отримані властивості в суміжних галузях. У статті проведено дослідження елементарних процесів у повздовжньому та поперечному напрямках розряду, в залежності від природних та штучних умов, за різних видів газового середовища, що використовується; за різних тисків газу та різного імпульсно-періодичного прикладання електричного поля. Показана відмінність властивостей розряду в інертних і молекулярних газах за різних конструкцій та площі електродів лабораторного пристрою. Встановлено, що зміна функціонального призначення між катодами та анодами не призводить до зміни форми розряду. Визначена присутність амбіполярної дифузії зарядоносіїв, котра діє на великій площі плазми. Встановлено часткову однорідність зарядоносіїв, котра спостерігається тільки вздовж поверхні плазми, а в перпендикулярному напрямку однорідність порушується. Визначена різниця енерговнеску у розряді, залежно від контрукції електродів, за інших рівних умов.Виявлені властивості плазми дають змогу їх більш ефективно використовувати для практичної реалізації у галузі електроніки та телекомунікацій та інших галузях промисловості.

Ключові слова: електроніка та телекомунікації; іоносферні збурення; технологічна плазма; вольт-амперні характеристики; ускладнені умови; просторовий заряд; локалізований розряд.