INVESTIGATION OF JUMPING PULSED ELECTRICAL DISCHARGE FOR PLASMA CHEMISTRY APPLICATION

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The behaviour of the pulsed discharge at atmospheric pressure between multiple needles- plane electrode has been investigated. This type of discharge has been used in our experiments as a suitable tool for plasma chemistry of CO_x, NO_x and SO_x, i.e. for effective decomposition of these radicals. The main advantage of it concludes to a phenomenon of spark jumping from one needle to another over whole volume of treated gas.

The behaviour of the pulsed discharge of such type has been studied with use of the optical registration method of discharge for each needle.

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1. INTRODUCTION

In our previous work [1] we have used so called multi-spark "jumping" pulsed discharge (it is successively jumping from one needle to another one) for CO_x, NO_x, and SO_x plasma-chemistry. Among the variety of electrical discharges this type of discharge is the effective one, as it can operate in a large volume of gas at high-pressure gas up to atmospheric one and above. Such discharge at most satisfies the conditions of performance of non-equilibrium plasma-chemical reactions.

The plasma-chemical reactions are being carried out with a high efficiency of molecules decomposition when working in a gas of high pressure. However at high pressures there are no well-elaborated effective electric discharges. One of perspective types of the discharge working at atmospheric pressure and above is the pulsed corona or pulsed spark [1,2].

The problem consists of how to treat the whole large volume of gas by such discharges. With this purpose the efforts are undertaken to force discharges to ran, jump, dance or something like all over the gas volume.

The pulsed discharge providing the performance in gas at high-pressure (atmospheric one and higher), allows increasing the efficiency of plasma-chemical technological processes. During a short time the optimum distribution function over energies of plasma electrons that is necessary for excitation of corresponding energy levels of electrons responsible for production of effective chemical reactions is shaped. The estimation of pulse length can be obtained under consideration of self-consistent processes in the discharge at the applied constant voltage or in RC - relaxation scheme.

In the present work the spark pulsed discharge between a set of needles and planar electrode is explored with the purpose of finding - out of a dynamics of a spark successively jumping from one needle on another and determining the probability of functioning of each needle for variety of parameters set.

Thus, in accordance with the formulated goal – to obtain at most the amount of resultants of reaction in gases – it is necessary to keep the followings:

-to use the repetitive mode of pulsed discharge provided that duty factor should provide the maximum products obtaining;

-the type of chosen discharge should correspond the requirements of its operation through all the interelectrode space.

Hence the highest efficiency of process of harmful radicals decomposition can be implemented in a multi-spark pulsed discharge with a geometrical configuration of electrodes like this: the expand system of needles - plane. This type of the discharge was used in ours experiments as appropriate one for plasma-chemistry of COx, NOx, and SOx, that is for their effective decomposition.

The object of our presentation is the investigation of the dynamics of the discharge between a set of needles and plane that is used in experiments on plasma-chemistry.

2. THE EXPERIMENTAL INSTALLATION

The experiments on *COx*, *SOx* dissociation and *Nox* synthesis in electric discharge were carried out on installation shown in Fig. 1.

The hermetic chamber *(CV)*, consisting of a glass cylindrical balloon (3), enclosed from above by a flange (6), and from below by a bottom (1), serves simultaneously as gas-discharge chamber and chemical reactor. Along an axis of the chamber two isolated electrodes are located: lower (4) and upper (5). The lower flat electrode is manufactured from aluminum and has the shape of a circle (diameter $3.8\cdot10^{-2}$m).

The upper electrode sets on a flange (6) with an opportunity of moving along an axis of *CV* for regulation of an inter-electrode gap. This electrode is changeable: its shape and size depends on a type of the used discharge. The electrode, movable along the axis, was a stainless steel rod, $8\cdot10^{-3}$ m in diameter, with a conical end. This electrode was used to ignite the arc discharge. For ignition of corona and spark discharge the similar rod was used with an additional electrode (comb), i.e. copper plate with the needles, manufactured from a copper wire, soldered to it, and directed to the lower electrode. The combs with 4, 5, 6 and 7 needles evenly distributed on its length (sizes of each needle manufactured: a diameter $5\cdot10^{-4}$ m, length $5\cdot10^{-3}$ m. Length of the comb is equal to a diameter of the lower electrode.

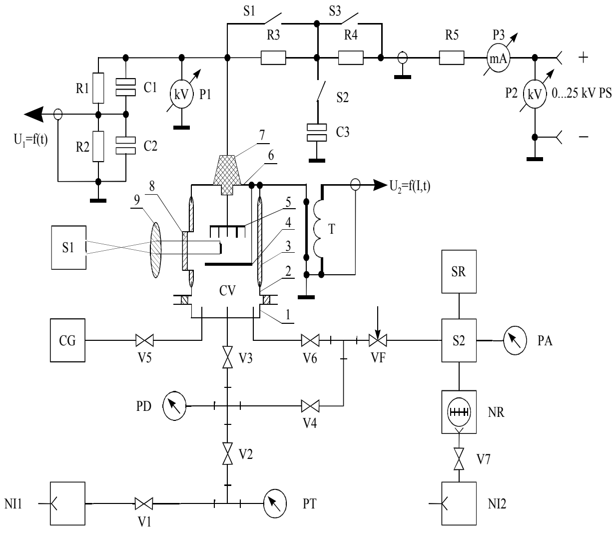

Fig. 1. Plasma chemical reactor:
CV - reactor chamber, CG - working gas chamber, NI1 - vacuum mechanical pump NVZ-20, NI2 - vacuum mechanical pump 2 NVR-5DM; NR - vacuum turbo molecular pump VMN-500; S1 - spectrograph DFS-452, S2 - mass-spectrometer MX7301, SR - two-coordinate self-recorder N-306, PD - deformation vacuum gauge; PA -ionization vacuum gauge, PT - thermal vacuum gauge; V1 ... V7 - straightway valves; VF - metering valve; R1 ... R5 – resistors; C1 ... C3 – capacitors; P1, P2 - kilovolt meters C96; T - transformer (Rogowsky belt); 1 - reactor bottom, 2 - lower flange of the reactor chamber, 3 - glass case of the chamber, 4 - lower electrode, 5 - upper electrode, 6 - upper flange of the chamber, 7 - insulator, 8 - quartz window, 9 - quartz lens

The electrodes of the discharge chamber are power supplied via ballast resistors from the controlled dc source ($U_0 =$ 0 to 30 kV, $I_{max} =$ 150 mA). The discharge chamber design provided the conditions for igniting the discharge of three types: corona and arc discharges with a constant current, and the spark discharge at a pulsed mode of operation.

The corona-discharge mode of operation is characterized by a high voltage applied to the discharge gap $U = U_0$ and a low current $I \leq$ 1 mA. At the arc-discharge mode of operation a considerable current $I \geq$ 15 mA sets in at a comparatively low voltage $U =$ (0.1 to 0.3)U_0 .

The spark-discharge mode of operation was realized in the case when relaxation oscillations appeared in the electrodes circuit and their power supply. These oscillations are characterized by sharp changes in the rate of increase and decrease in the voltage and current.

For translation of the scheme in a mode of the relaxation generator the condenser with capacity of C =150...1000 pF was connected parallel to discharge gap. The quantity of capacity at fixed value of resistance of a ballast resistor determines the time of charging of the condenser up to a breakdown voltage of a discharge gap and, hence, the repetitive frequency of a spark pulsed discharge. Besides the repetitive frequency of discharge pulses depends on an inter-electrode gap and voltage of the power supply.

The pressure of working gas in the chamber of a reactor *(CV)* can be changed and supported in a wide band of values (from several Torr to atmospheric pressure) with the help of instrumentation of leakage and pumping.

For the check of an initial and final composition of gas the mass-analyzer *(S2)* is mounted to the reactor. Registration of mass spectra is carried out by two-coordinate self recorder *(SR)*. The obtained mass spectra will be used for calculation of the content a gas components.

The inter-electrode gap is chosen depending on applied voltage in the limits $(1,2\ldots1,8)^{-2}$ m. The voltage of the power supply is set from 15 up to 25 кV, the breakdown voltage of the discharge gap under these conditions reaches 10…13 кV, resistance of the ballast (charging) resistor R =2,5 MΩ. Repetitive frequency of discharge pulses f =(0,3…1,2) kHz, pulse duration $\approx 10^{-6}$s, pulse current ≈80 A.

The spark discharge in each gap very often develops not along the shortest trajectories between electrodes, but various more longer trajectories, which are placed inside a cone with vertex at an edge of a needle of the upper electrode and basis on the lower electrode with a diameter of a circle approximately equal to a half of value of the inter-electrode gap. Because of continuous random displacement of a spark in discharge gap a registered light radiation appears modulated on intensity.

The investigations of features of a spark discharge in air at atmospheric pressure is carried out on the experimental set up with use of plasma chemical reactor installation (Fig. 1), which construction was somewhat changed.

The experimental scheme is given in Fig. 2. For deriving the access to interelectrode gape the glass balloon was taken off. On the upper electrode (1) the comb with 4 needles was set. The lower flat electrode is exchanged on ridge one consisting of thin metal strips set under each needle of the upper electrode (2). To lower an interference level in measuring circuits from an pulsed discharge and to avoid the danger of a defeat by an electrical current, the non-contact method of study of spark behavior in inter-electrode gape is applied.

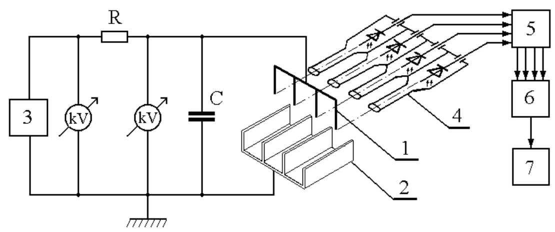

Fig.2. Scheme of measurement. 1-upper electrode, 2-lower electrode, 3-power supply, 4- photo-receivers, 5-amplifiers unit, 6-analoge-digital converter, 7-computer

From four discharge channels the light radiation accompanying each needle – strip discharge, is registered by the help of 4 photo-detectors and transformed in electrical signals. With the purpose of preventing lightening from the discharges in the neighbor channels the receiving photodiodes set in tubes with anti-reflection of light coating and small aperture angle. All photo-detectors are joined in one screened box (4).

The signals relevant to the sequence of spark discharges in each channel from photo-detectors through 4 channel amplifiers (5) enter on 4 channel analog-digital converters (6). The arbitrary samples of these signals by duration 0.1 and 0.2 sec with a period of digitization $3.2\cdot10^{-6}$ and $6.4\ 10^{-6}$ sec in a binary code are recorded in a computer memory (7). Further the obtained by this way data are computed with the help of corresponding mathematical programs.

3. EXPERIMENTAL RESULTS

The light radiation as a sequence of short-term flashouts from discharges in each of four discharge gaps with the help of a photoreceiving device is transmuted into four synchronous sequences of electrical impulses. Converted with the help an analog-digital converter in a binary code the arbitrary samples of a pulse sequence by duration 0,1 or 0,2 sec are inlet in the computer and after handling of results are output as the diagram $A=f(t)$, where A – amplitude of an impulse, t – time.

In Fig. 3 and 4 two groups 4 synchronous pulse sequences from four discharge gaps obtained for two different instants are submitted.

Comparing pulse sequences in Fig.3, it is possible to see, that in the first and second gaps the quantity of the discharges during interval t = 0,1sec is more than in others. Nevertheless, in other two gaps the discharges also occur, but they are more rare. From Fig. 4 it is visible, that in this interval of time the discharges arise more often from edges of needles in the first and third gaps. In the others two gaps the discharges will not stop, though their quantity is less. If to compare such sequences in other time intervals, it is possible to mark, that the discharge jumps from one needle to another, without concentration on any one chosen needle.

4. CONCLUSIONS

In present work carried out examination of features of development of a pulsed spark discharge in air at atmospheric pressure in gap between an electrode as 4 needles and linear electrode. The applied noncontact method of recording of the discharges in an interelectrode gap has allowed to register synchronous sequences of electrical impulses relevant to light radiation from each needle, and to compare them.

The obtained results testify that in a pulsed spark discharge of such configuration all edges without exterior interference operate practically with identical probability. In earlier our experiments at use of a great many of needles, at any rate, visually character of the discharge did not vary. Therefore, having extended obtained results of the given work on multispark of systems of electrodes, it is possible to guess, that in such configuration of electrodes there is an opportunity to realization the discharge in large volumes, that represents essential interest for plasmachemistry.

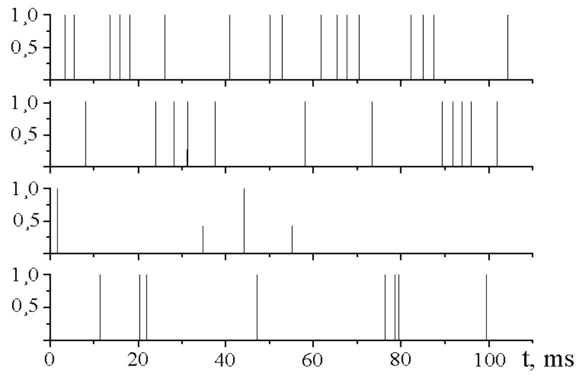

Fig.3. Sequence of discharge pulses in four channels during 0.1 sec for the first instant

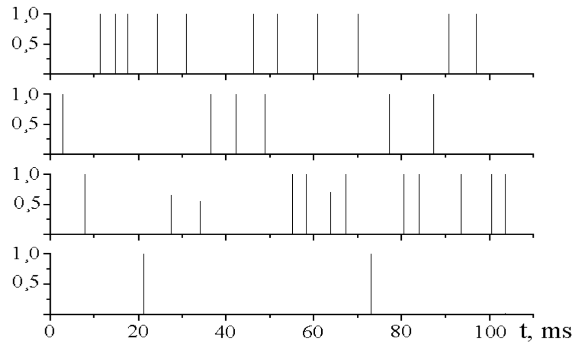

Fig.4. Sequence of discharge pulses in four channels during 0.1 sec for the second instant

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