# MICROSECOND MICROWAVE GENERATION IN THE DIODE AND ACCOMPANYING PHENOMENA

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The processes of a gas desorption and ion production were investigated during generation of microwave pulses in a microsecond vircator. The influence of vacuum conditions was investigated and the velocity of cathode plasma was determined. Specific values of gas desorption and the partial composition was investigated for different cathodes. The parameters of the diode electron accelerator are the followings: beam energy 300 keV, beam current up to 10 kA, half-period 1,5 μs. Cathode and anode diameters are 10 cm and 20 cm, respectively. Vacuum chamber diameter is 50 cm, anode-cathode gap is 2 cm. The duration of microwave radiation is 0,5 μs, wavelength is about 10 cm, output microwave power is of about $1.5 \cdot 10^8$ W. The amount of gassing reaches 0.3 n.cm$^3$/pulse. Ion energy reaches 200-300 keV value.

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## I. INTRODUCTION

For creation of high-power microwave pulse generators of various applications it is necessary to know**,** apart from the information about the microwave generation itself, a number of accompanying effects determining the energy-weight and resource characteristics. Therefore, in the present paper besides the researches on microwave generation, investigations of values and partial composition of gassing, energy and direction of ion fluxes were performed**.**

## II. THE SETUP AND DIAGNOSTICS

The experiments were carried out at the setup VGIK-1 [1] (Fig. 1) with the following diode parameters: voltage up to 300 kV, current about 10 kA, the shape of pulses of current and voltage is close to the sinusoidal one with duration of a half-period about 3.5 μ s. The size of the anode - cathode gap was varying from 10 up to 25 mm by moving the cathode of 10 cm in diameter. The anode is the grid from 20 cm diameter stainless steel with a transparency of about 80%. The cathode is grounded, a pulse of positive polarity moved on the anode. Researches of a microwave generator of such type are described in the papers [2, 3]. The vacuum chamber of the diode is the pipe from stainless steel with about 50 cm diameter and 100 cm length. In the field of the diode there could be an external magnetic field up to 2 kOe, parallel to the diode axes, i.e. in the anode-cathode direction.

At the first stage of experiments the system was pumped with the use of nitrogen-helium sorption and condensation cryopumps and, at the second stage**,** with diffusion oil pumps. The vacuum chamber is made by a usual, not superhigh vacuum technology, has rubber seals and could be heated no more than up to 80°?, however separate parts, for example the cathode, could be heated up to 500°?. The operating pressure in a system is about $1 \cdot 10^{-6}$ Torr for cryopumps and about $4 \cdot 10^{-5}$ Torr for diffusion pumps.

The installation is provided with the following diagnostic tools: belts of Rogovsky for current measurement, and a capacity divider for voltage measurement, x-ray sensors of an integral type, microwave calorimeters of a horn and planar type, microwave diodes with attenuators, vacuum sensors and a mass-gas-analyzer. Magnetic analyzers using track prints were used to measure the energy and composition of the ionic component.

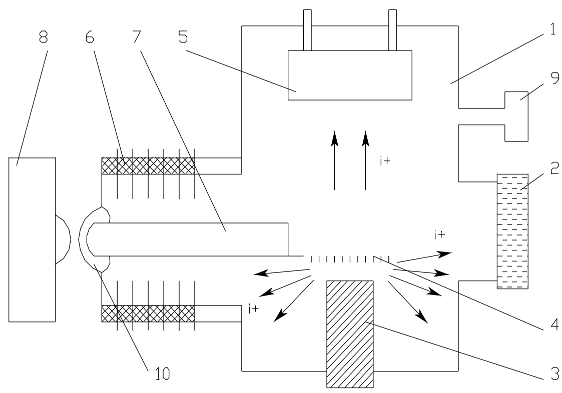


***Fig. 1.*** *Schematic diagram of the device. 1– vacuum chamber, 2– output window, 3 - cathode, 4– anode, 5–cryopump, 6–accelerating column, 7–high-voltage current input, 8–Marx generator, 9–mass-spectrometric analyzer, 10–pure zone.*

## III. EXPERIMENTAL RESULTS

The oscillograms of diode current and diode voltage, the shape of microwave signal are shown in Fig. 2. The comparison of the shape of microwave signal with the calorimetric data determines the value of microwave power at a level of 150 MW. The calorimeters are graduated by current and microwave signals and have sensitivity about 10 J/K with an accuracy of temperature measurement by gas thermometers of $5 \cdot 10^{-2}$ K. The value of wavelength is in the range 10-11 cm. It was estimated by the help of the flashing tubes and the calorimeter with the adjusting plunger, using the given parameters of beam and geometry of the system without magnetic field. The duration of a microwave pulse essentially depends on the type of the cathode. For flat carbon and multipin cathodes it can vary from 200 up to 500 ns.

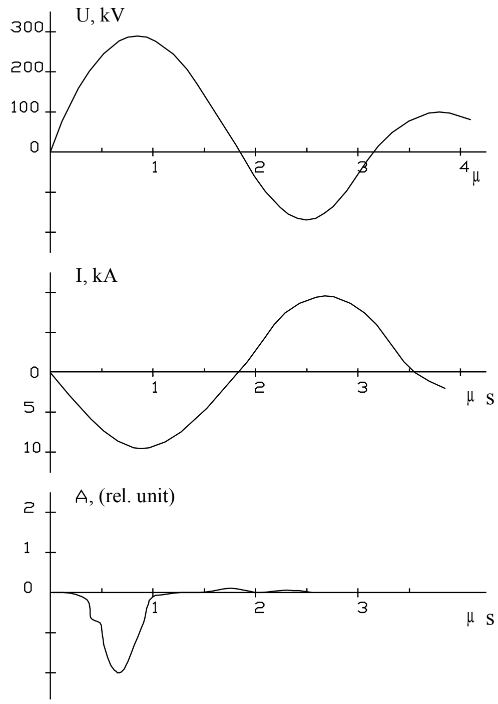


*Fig. 2. The oscillograms of diode current and voltage of microwave signal.*

The arrows show the directions of ion fluxes in Fig. 1, and the main direction is equatorial. The natural hit of ions on the cathode was not registered. The registered energies of ions lie in the range of 50 - 250 keV. The main composition of the beam ions is iron, carbon and hydrogen. The actuation of a magnetic field reduces an equatorial flux. At present, we cannot distinguish static and microwave acceleration. The availability of ions of iron is connected with ablation processes on the anode grid, where the level of energy release achieves 10-50 J/cm$^2$. The destruction of the anode grid occurs, as a rule, at quantity of pulses exceeding $10^3$. Availability of graphite cathodes, pumping facilities and the materials of the diode determine the presence of ions of carbon and hydrogen. Their availability determines the velocity of cathode plasma motion as well, which lies in the range 3-4·10$^6$ cm/s and, accordingly, the duration of a microwave pulse.

Deposition of carbon on the anode grid also gives a carbon ionic component. An interesting observation is the availability of a pure zone, i.e. a zone without the deposition of films in the field of a ring with width of about 2 cm around a high-voltage current input in accelerating tube. This can testify to magnetic shielding and focusing of ion fluxes coming from the diode. Besides, a special type of a print of the cathode on an output window allows assuming that the role of a current in a high-voltage current input is exhibited at the opposite side as well.

To obtain the information about pulse gassing the vacuum chamber of the diode immediately before the start of Marx generator was separated from the external pump by valve KR-100. The start of Marx generator operation was accompanied by a leap of chamber pressure, which was registered by a recorder.

The amplitude of a pressure leap registered is proportional to the value of complete gassing only in that case, when the pump of internal arrangement completely is disconnected, i.e. warm. At the presence in a screen of liquid nitrogen of this pump, the chamber pressure was lowered up to 4-3·10$^5$ Torr, and the registered pressure leap will be proportional to quantity of noncondensing gases on a nitrogen surface ($H_2$, $N_2$, $CH_4$, $CO_3$). It is explained large (about 2·10$^4$ l/s) pumping speed of noncondensing component ($H_2O$, $CO_2$) on a nitrogen surface and final constant of time of a measuring circuit. After filling up of liquid helium in the helium condensation pump (HCP) of internal arrangement the value of the registered pressure leap is determined by total amount of hydrogen, desorbed for a pulse and besides by relation between pumping speed and resolving ability of the measuring system.

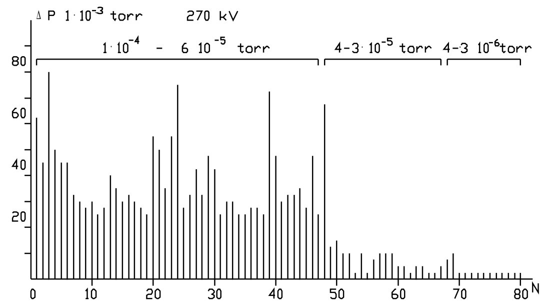


*Fig. 3. Typical sequence of pressure changes ΔP from pulse to pulse in experiments with the grid anode, N is the serial number of pulse.*

The diagram in Fig. 3 shows a typical sequence of pressure changes from pulse to pulse for the mentioned above cases. From Fig. 3 it is seen, that already after the first 5-10 pulses the pressure jumps reach some almost constant average level. The pressure in the diode chamber behaves in a similar way, remaining approximately at the same level, despite of increasing quantity of pulses. After liquid nitrogen filling up into the HCP screen of internal arrangement, the average value of registered pressure jump drops approximately in 4 times. Under the supposition that thus the average level of the gassing has not varied, such decreasing of pressure jump testifies that there is approximately to 50% content of components easily condensed at T= 78 K (with corrections on the sensitivity of the sensor PMI-2 to various gases) in its composition. The filling of liquid helium into the HCP lowers the value of the registered pressure jump more than in 10 times as compared to the initial one.

Thus, the experiments have shown that under conditions close to conventional ones, the average value of complete gassing in the vacuum chamber of the diode makes 1,0-0,3 cm$^3$ per pulse and grows with the pulse power (Fig. 4). We have not observed a significant reduction of the average level of gassing (and pressure) in accordance with increasing a number of pulses (up to

150 in a series). From our point of view, the cause of the absence of training and cleaning of vacuum surfaces can be the gas flux coming from such source as a caprolan isolator. Furthermore, the pre-breakdown effects stimulate the value of this flux with applying of voltage pulse to the diode input. This gas is actively adsorbed by the surfaces cleared during the previous pulse and it is desorbed under the action of a consequent pulse. The energy output of desorbed particles makes about $10^3$ eV or $10^2$ particles per beam electron.

As show additional experiments, not only the electrodes of the diode gap are subjected to clearing, but also the areas neighboring to it. For example, the replacement of the flange from stainless steel (located at a level of the diode isolator at an angle of 90° to the latter) with flanges from organic glass resulted in increase of the average value of gassing at fixed voltage by a factor of five (point I, Fig. 4).

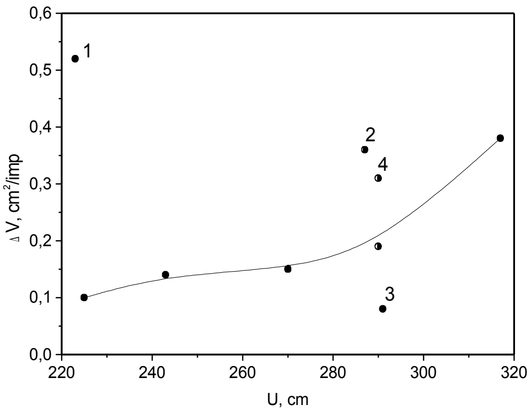


***Fig. 4.*** *Averaged gassing vs diode voltage.*

Despite the fact that the surface of the anode was increased no more than by 20% in experiments with the anode of disk type it was found that the average value of gassing on a comparison with the grid anode was increased in 2 times (point 2, Fig. 4). This fact can be explained by effective reflection of particle fluxes and radiation emission to the lateral surface of the chamber by the anode of disk type. The magnetic field (1.2 kOe) application resulted in a common reduction of pressure jump and average value of gassing (point 3, Fig. 4). It is explained by the fact that the magnetic field lines are mainly parallel to the lateral surface of the chamber and the electrical discharge in a longitudinal magnetic field is localized in the area of the cathode-anode gap.

The contrary effect is observed in experiments with the grid anode when applying the magnetic field (point 4, Fig. 4). A source of gassing increase in this case indicates the occurrence of a precise blackening circle of the cathode print on the bottom of the HCP nitrogen screen of internal arrangement located 20 cm higher above the grid anode. Thus, here, the increase of gassing occurs as a result of gas desorption from the surface of the nitrogen screen under effect of cathode plasma fluxes spreading along lines of magnetic field and of some part of the electron beam and ions.

***Gas composition***

| Gas | $H_2$ | 28 | $H_2O$ | $CH_4$ | $CO_2$ |
|---|---|---|---|---|---|
| $\Delta P$, $10^{-6}$ Torr | 3300 | 90 | 57 | 39 | 15 |
| % | 93 | 3 | 2 | 1 | 0.4 |

## IV. SUMMARY

Experiments with isolators and cathodes from various materials showed, that, despite of existence of some differences in background mass spectra, the value and the composition of the pulsed gassing (PG) do not significantly depend on the isolator and cathode material. A specific PG composition in experimental conditions under consideration obtained as the average value of large number of pulses (up to 150 per peak), is represented in Table. As is seen, some gases give the contribution to the PG composition at a level more than 1 %. A dominant gas among them is hydrogen. The experimentally established fact that isolator and cathode materials have no strong influence on the PG composition indicates that the main source of hydrogen is its reduction from the walls of the vacuum chamber and cathode.

As follows from experiments the essential problem in development of microwave generators operating in the frequency mode is the pulsed gassing that causes complication of the vacuum system. Therefore, it is supposed to elaborate the measures for gassing reduction.

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