The Combined Discharge for Receiving of Neutrons

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Abstract – Accelerating tubes with virtual anodes – injective and break-down collapsotrons – have been developed for driving the neutron fluxes. The plasma blob produced with a plasma gun and icnjected into the discharge chamber is used as a central electrode in the injective collapsotron. A virtual anode is produced in the break-down collapsotron at the initial stage of a multichannel breakdown near the surface of a conical insulator. The plasma blob formation within the pipes of both types is preceeded by the emergence of a spherical ball lightning type product in the near-electrode space due to the fast electrons thermalization. In the discharge chamber – a hollow resonator – the conditions for an effective virtual anode are produced in both types of accelerating tubes.

1. Introduction

The electric discharges in a gas under low and middle pressures are of a definite interest for solving a number of problems. In the plasma focus facilities two geometries of the discharge cell proposed by N.V. Filippov [1] and by J.W. Mather [2] are applied. The only difference in the cell geometries is in the insulator configuration. In the plasma focus discharge can single out three characteristic stages in its operation. The first stage is related with a breakdown near the surface of the insulator located between coaxial electrodes. The current plasma shells (CPS) which have a structure similar to that a leader in the spark discharge emerge at this stage in the inetrelectrode space. The applied voltage drop occurs at this stage. At the main stage of the pulse, partly-produced current plasma zone is moving with a velocity of 10^7 cm/s towards an electrode system cut. The further shaping of the current plasma shorting zone and its motion toward the electrode system cut occur simultaneously. At the final stage – at the current plasma shorting zone approach towards the and face electrode system – a collapse occurs due to a conversion of the CPS – multiplicity in the upper part of the anode. At the last stage a hard bremstrahlung and fast electrons emerge, as well as a neutron emission occurs. At the same stage of a discharge an anomalous plasma resistance is also observed.

One should note that the energy transfer process from the storage of charges to the loading in the known discharge cells is realized in a way far from the optimal one. A discharge in the inetrelectrode space, the volume of which is rather significant, is used for producing a current plasma closing zone at the main stage of the pulse duration. The plasma production time is a rather long one. In this case, the energy to the ionized particle ratio *W*/*N*, is low. The plasma erosion disconnector deficiency in comparison with a plasma focus discharge is an essential energy loss in the space.

Note the very fact that the current plasma closing zone is necessary for the transition to a collapse stage. An optimal plasma focus device is such where the second stages related with the plasma production is absent. The process of operating in a plasma focus device should consist of a breakdown stage and of a collapse one.

2. Solution of a Problem

An analisis of the studies with diodes having a virtual cathode [3, 4] confirms the fact that the usage of a virtual electrode allows one to produce the fast electron beams with an energy twice exceeding a value corresponding to the applied voltage. The current of fast electrons in the direct diode [4] was equal to 1 kA or 25 percent of the current in the main circuit (4 kA). A virtual cathode in the direct magnetically-isolated diode in [4] was produced due to a gap between the current-receiving collector and the anode. The collector potential in that case coincided with the cathode potential. At the initial discharge stage, the electrons produced as a result of an explosive emission after the passage of an accelerating potential difference between the cathode and anode underwent of the deceleration by a field between the collector and the anode. As a result of an abrupt energy drop by electrons, their thermalization took place, as a result of which a low density plasma emerged in the space. One can judge about its emergence by the signal oscillations upon the voltage oscillogram. A repeated beam electron passage in such a plasma results in the charge separation, generation of its own electromagnetic radiation. Note that the results produced in [3, 4] served as a basic for creating the sources of microwave radiation-vircators.

A promising neutron source can be produced on the basis of a combined discharge including the elements characteristic for the plasma opening switch and for the plasma focus device. The plasma needed for the fast particle generation under passage of current-plasma shells can be produced not with the help of the CPS but be applied to the cathode cavity from outside with a plasma gun. In that case, there is no necessity in the extended metallic anode which take place in the J.W. Mather cell and screening an effect of virtuality.

The function of a virtual anode will be more effectively realized by an anode plasma.

In [5, 6] it has been realized that the CPS-emergence is preceeded by the emergence of an electric domain in the near-electrode zone. The birth of a domain is accompanied by the generation of transversal electromagnetic waves. Due to the waves the charged particle acquire an energy exceeding the value corresponding to the applied voltage [7]. It is not hard experimentally to show that the conditions for producing an effective virtual electrode are realized under a breakdown between the cathode and the anode plasmas and at the CPS-entry into the plasma within the central zone of the chamber.

3. Production of a Virtual Electrode in the Space under Atmospheric Pressure

A plasma gun was used in the experiments. A high voltage from the pulsed generator, capacitive type (U = 21 kV, C = 0.5 μF), was applied to its electrodes.

At the distance of 6 cm from the gun exit, a spherical electrode, 14 mm in diameter was located in some experiments. The following parameters were registered: applied voltage, a current through the gun circuit, current in the near-electrode space and microwave radiation. The plasma luminosity was registered with an electron-optical converter under the exposure of 20 ns long. In some experiments the spherical electrode was used as a collector, being earthed through a shunt, i.e. it has a potential of the anode. A typical waveforms of applied voltage (upper trace) and the discharge current for gun without a spherical electrode are given on Fig. 1.

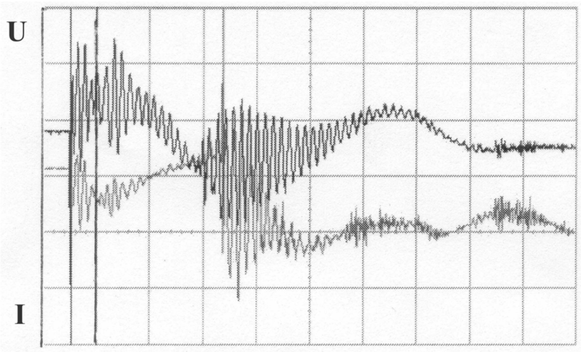
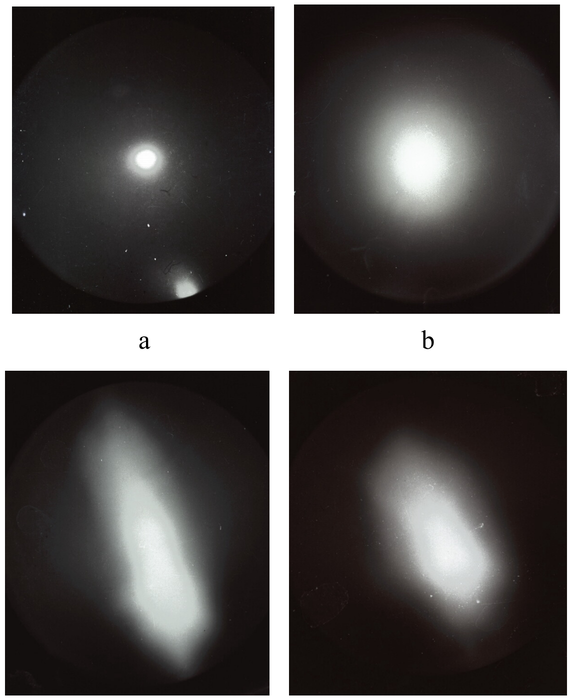


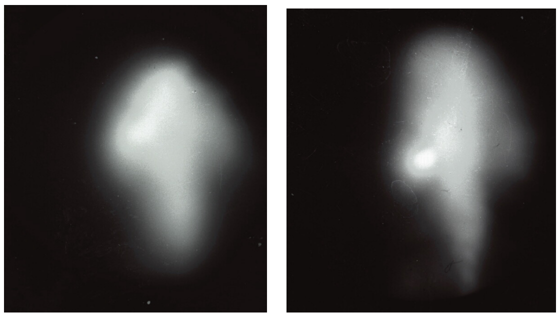
Fig. 1. Waveforms of applied voltage (upper trace) and of discharge current (lower trace) for a plasma gun

The high-frequency oscillations of signals on the oscillograms are accompanied with separation of charges. In an initial stage of discharge there is emerge an abnormal formations such as a globe lightning. The images of luminosity in space are given on Figs. 2 and 3.



a b c d

Fig. 2. The images of luminosity in space for four intervals of time in initial stage of discharge. An exposure – 20 ns



a b

Fig. 3. The image of luminosity plasma in a main stage of impulse for two intervals of time

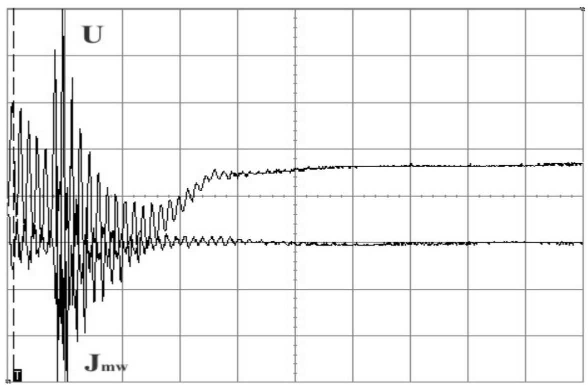


Fig. 4. Waveforms of applied voltage (upper trace) and signal of microwave radiation (lower trace). Time sweep – 1 μs/div

At installation of a spherical electrode there is a change of parameters circuit. A breakdown is accompanied by a generation of a microwave radiation and by the emergence of fast electrons and ions. The waveforms of applied voltage, signal of microwave radiation, current in a main circuit and current on collector (a spherical electrode) are given on Fig. 4 and Fig. 5 accordingly. From results of measurements (Fig. 5) follows, that current into collector is less, then current in a main circuit.

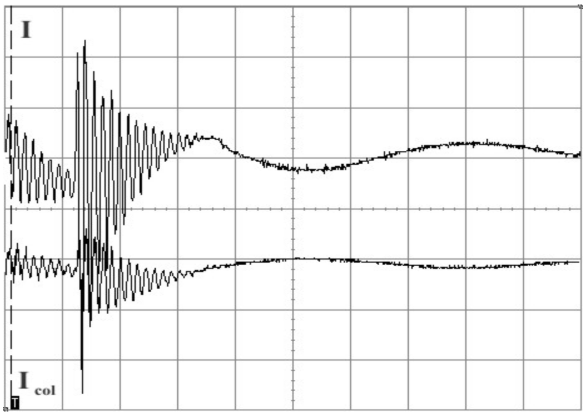


Fig. 5. Waveforms of discharge current in a main circuit (upper trace) and a current on collector (lower trace). Time sweep – 1 μs/div

4. The First Experimental Results on "Prometheus"

The first experimental were done at the "Prometheus" facility. The facility included some capacitive energy storage, rectifiers, triggering and control units, as well as diagnostic means. The commutation of spark-gaps was realized with a pulse generator GI-1 and controlled with an oscillograph. In the experiments with a break-down collapsotron commutated storage mounted on the basis of low inductive high voltage capacitors, IK-100-0.4-type, was used. The storage had the following parameters: $U = 50$ kV, $C = 2$ μF, $W = 2.5$ kJ.

The storage triggering was provided with a three electrode spark-gap having a distorted field. In the experiments with the injective collapsotron the storage based on the K41I-7 – capacitors. The parameters of the storage were a following: $U = 20$ kV, $C = 25$ μF, $W = 5$ kJ. In this case, the storage triggering was provided with a plasma gun producing a virtual anode inside the coaxial cathode. The cathode diameter was equal to 36 mm, its length was equal to 88 mm. The shope angle of a working insulator surface towards the axis was equal to 45 degrees. The spherical anode diameter in the break-down collapsotron was equal to 10 mm. An essential erosion of the spherical anode, plasma gun face surface and of the conical insulator surface was detected. The erosion is related with the presrnce of the intense fast ion and electron micro-beams which are produced under charge separation. In the injective collapsotron observed rise of voltage-which is characteristic for the plasma erosion switchs. The measuring of neutron fluxes were not made.

Conclusion

The design is based on the qualities characteristic for a plasma opening switch and for plasma focus discharge, as well as on the results produced under study of the physics of discharge in a gas. The part of results were obtained author [5–7].

The devices have a number of advantages in comparison with the plasma focus devices. These advantages are the following:

1. the plasma produced in the gun a special type has a higher value of W/N than that under the breakdown in a classical plasma focus discharge;
2. the plasma injection also allow one to realize the chain commutation, when the energy is supplied from the main storage without assistance of an ex ternal commutator;
3. the plasma injection into a central part of the device or a breakdown near the surface of a cinical insulator allows one to realize an effective virtual anode.

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