PLASMA CATHODE SWITCHES BASED ON THE CAPILLARY DISCHARGE IN SUB-MILLIMETER SLITS*

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A series of experiments on investigation of switches (eptrons [1,2]), which represent a combination of capillary discharge with plasma cathode, is presented. Such devices are able to provide a delay of the breakdown development up to hundreds of ns with a switching time ~ 1 ns in a wide range of pulse repetition frequencies (100 kHz and higher) and voltages (~ 5-200 kV) at switching currents up to units of kA.

The first part of the report presents the results of studies devoted to the influence of different design parameters of the switches separate elements (cathode node, capillary structure, external conductive shield of the capillary). In particular, the influence of the capillary channel shape and its width in the range from 0.2 to 1 mm is considered. A hollow cylindrical Ti cathode with an inner diameter of 2.6 cm and a length of 90 cm with and without additional ignition was used as a cathode assembly. A rectangular hole (60×6 mm) was made in the side surface of the cylinder into which the capillary structure was integrated. Studies were performed using helium with a pressure of 1-20 mbar as operating gas. To form high-voltage pulses on the storage capacitance a solid-state generator with pulse repetition frequency up to 200 kHz in a burst operation mode was used.

In the second part of the report the results of gas type and pressure influence on the switch operating parameters for the capillary construction with a rectangular slit of 10x0.3 mm cross-section and length of 60 mm fabricated from Al_2O_3 plates are presented. Switch cathode node consisted from two oppositely located 3 mm long accelerating gaps limited by SiC cathodes and a molybdenum grid with a geometric transparency of 90%. The accelerating gaps were separated by a 10 mm long drift space. Studies were performed with He, Ne, Ar, H2 in the frequency range of 1 - 20 kHz at 20 - 30 kV and an active load of 33 - 300 Ohm. Comparative characteristics in terms of breakdown delay time, switching time, efficiency under the specified conditions are presented. The main difference in the performance with different gases is observed in the first 5 ns, when the discharge is formed. Nevertheless, the total efficiency of energy transfer to the load does not change by more than 10% and lies in the range of 73-82%. Thus, the investigated switch is able to efficiently operate with various gases in a wide range of conditions.

Also, the results of excitation of various gas-discharge laser media by generators based on the presented switches are demonstrated. For copper, calcium and barium vapor lasers there was a many-fold increase in the average output power in comparison with the case of pumping by a traditional generator based on magnetic pulse compression with a longer excitation pulse edge (~ 30-50 ns).

REFERENCES

[1] Bokhan, P. A., Belskaya, E. V., Gugin, P. P., Lavrukhin, M. A., Zakrevsky, D. E., & Schweigert, I. V. “Investigation of the characteristics and mechanism of subnanosecond switching of a new type of plasmas switches. II switching devices based on a combination of ‘open’ and capillary discharges—eptrons,” Plasma Sources Sci. Technol., vol. 29. no. 8, p. 084001, 2020.

[2] P.A. Bokhan, P.P. Gugin, M.A. Lavrukhin, I.V. Schweigert, A.L. Alexandrov, D.E. Zakrevsky, “A high-voltage subnanosecond sharpener based on a combination of ‘open’ and capillary discharges,” J. Phys. D: Appl. Phys., vol. 51, no. 36, p. 404002, 2018.

* The work was supported by the Russian Science Foundation under grant No. 19-19-00069.