ON THE INFLUENCE OF A CATHODE SHAPE ON THE PARAMETERS OF CURRENT PULSES OF RUNAWAY ELECTRON BEAMS AT APPLYING VOLTAGE PULSES WITH A RISE TIME OF 200 NS*

V.F. TARASENKO, D.V. BELOPLOTOV

Institute of High Current Electronics, 2/3 Akademicheskii Ave., Tomsk, 634055, Russia, E-mail: rff.qep.bdim@gmail.com

Runaway electron beams generated during the breakdown of gaps with a cathode having a small radius of curvature are currently obtained in various gases at pressures from hundreds of Pa to thousands of kPa. Their parameters were measured in different conditions with a high temporal resolution [1]. However, such measurements were carried out under conditions of high overvoltages when applying voltage pulses with a subnanosecond and nanosecond front duration. In practical applications, voltage pulses with a rise time of 10^{-7}–10^{-6} s are widely used [2]. There are very few data on direct measurements of the parameters of runaway electron beams under these conditions. Noteworthy is the work [3] of 2018, in which studies were carried out with the rise time of ≈ 500 ns.

The purpose of this work is to study the influence of the cathode design on amplitude-time parameters of runaway electron beams at applying voltage pulses with the rise time of 200 ns.

The experimental studies were carried out on setup that allows measuring subnanosecond runaway electron beam current pulses with temporal resolution up to 100 ps. A GIN-35NP homemade voltage pulse generator was used. Different cathodes were used. The first one was made of a needle with a length of 5 mm, a base diameter of 1 mm, and a rounding radius of its tip of 75 µm. The second was tube with a diameter of 6 mm and a wall thickness of 100 µm. The third was made of a ball with a diameter of 14 mm. The grounded electrode was a plane. The gap width was 8.5 mm. The generator produces negative voltage pulses with an amplitude of up to 35 kV, the rise time of 200 ns, and a pulse duration $\tau_{0.5} \approx 270$ ns. To measure the parameters of a supershort avalanches electron beam (SAEB) [1], the grounded plane electrode was made of a grid. The SAEB current was measured with a 20-mm collector placed behind the grounded electrode. The grid had the mesh size of 400×400 µm and a transparency of 62%. In some experiments, a 2-µm kimfol ($C_{16}H_{14}O_3$) film coated with a 0.2 µm-thickness aluminum layer, as well as a 10-µm Al foil were used as the grounded electrode. The kimfol passes electrons with an energy of 10 keV and higher. The Al foil passes electrons with an energy above ≈40 keV. They were used as filters. The electrical signals from a capacitive voltage divider and the collector were recorded with a Keysight Tech MSOS804A digital oscilloscope (8 GHz, 20 GS/s). The bandwidths of a current shunt made of chip resistors and the 20-mm collector were no higher than 4–5 and 6 GHz, respectively.

It was found that the shape of the cathode significantly affects the duration of SAEB current pulse, its amplitude and shape. The largest amplitudes (≈ 90 mA) were observed with the tubular cathode at a pressure of air of 12.5 kPa. Saeb current pulse duration was $\tau_{0.5} \approx 130$ ps. Two pulses with different duration, amplitude and energy of electrons were observed with the needle cathode. When using the ball, the duration and amplitude of the beam current pulses were $\tau_{0.5} \approx 250$ ps and ≈ 4 mA, respectively.

Studies performed with a four-channel ICCD camera showed that the breakdown occurs via the development of streamers starting from the cathode. The diameter of the streamer depended on the radius of curvature of the cathode, and was the largest with the smallest radius of curvature (needle cathode). As the air pressure increased to 100 kPa, the amplitude of the beam current decreased.

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* The work was performed under the grant RFBR according to the research project No. 18-52-53003_GFEN_a.