Effect of secondary electron emission on subnanosecond breakdown in high-voltage pulse discharge

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A subnanosecond breakdown in high-voltage pulse discharge is studied in experiment and in kinetic simulations for mid-high pressure in helium. It is shown that the characteristic time of the current growth can be controlled by the secondary electron emission. We test the influence of secondary electron yield on plasma parameters for three types of cathodes made from titanium, silicon carbide and CuAlMg-alloy. By changing the pulse voltage amplitude and gas pressure, the area of existence of subnanosecond breakdown is identified.

Recently serious attention is paid to the study of physical phenomena of subnanosecond current development in discharge plasma in super-high-electric fields at mid- and high-pressures.

In this paper, in the experiment and in PIC MCC simulations we study the breakdown development in the high voltage discharge with 3 types of cathodes made from different materials. All these materials have enhanced secondary electron emission yield. Our purpose is to find a way to decrease the discharge breakdown time by testing different cathode materials and changing the gas pressure and voltage. The breakdown in the high-voltage pulse discharge in helium is studied in the experimental cell with two round cathodes with the total area of 1.6 cm2 placed 6 mm apart. A mesh-anode is placed between the cathodes. The pulse voltage is simultaneously applied to both cathodes and two oppositely directed electron beams are generated due to cathode emission. The voltage amplitude ranges from 4 kV to 12 kV and P=10-35~Torr. The cathodes are symmetrically connected to the external low-inductance circuit and the mesh-anode is grounded. The pulse shape is registered with the low-inductive resistive divider with the rate about 20:1 using oscilloscope Tektronix DPO 70804C with a bandwidth of 8 GHz. The experimental details were described in [1]. In the experiments, the cathodes made from titanium (Ti), silicon carbide (SiC), and CuAlMg alloy were tested. All these materials have large SEE coefficient γ_e, but the dependence of γ_e from the electron energy is different. In our simulations, we solve Boltzmann equations for electrons, ions and fast neutral atoms. Poisson equation describes the electric potential. The details of the model can be found in [2]. The effect of P on breakdown time is shown in Fig.2. The record switching time for SiC and CuAlMg-alloy is τs <0.4ns and for Ti is 4-5 times larger. In conclusion there is a specific range of discharge parameters, 5-10 kV and P=15-35 Torr, within that the record switching time τs <1 ns can be achieved.

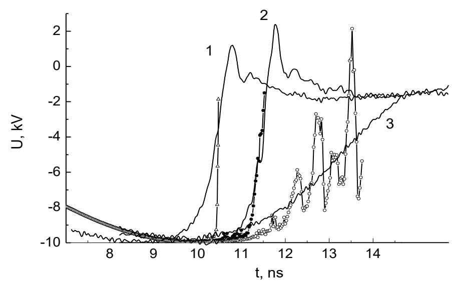

Fig. 1. Voltage measured (solid lines) and calculated (lines with symbols) cathodes from titanium (1), silicon carbide (2) and CuAlMg-alloy (3) for Ua=10 kV and P=25 Torr.

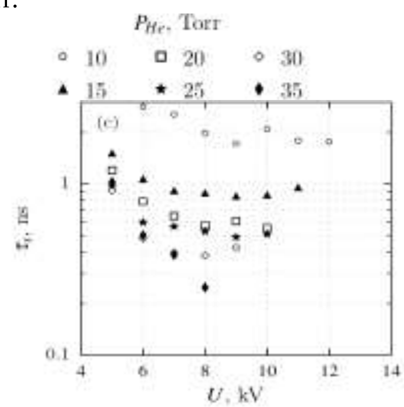

Fig. 2 Breakdown time via U for CuAlMg-alloy cathode for different P.

[1] Bokhan P A et al 2016 In: Generation of runaway electron beams and x-rays in high pressure gases (NY: Nova Science Publishers Inc) 221
[2] I.V. Schweigert, et al PRE, 90, 051101(R) (2014); I.V. Schweigert, et al PSST 24, 044005 (2015)