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Three regimes of high voltage breakdown in a high current plasma switch for modern electric grid[1]

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The high voltage breakdown of gases is important for many applications, e.g., for electric insulation, high-power switches, and tokamak start-up. However, low pressure and high voltage breakdown mechanism is poorly understood, because of necessity to include into consideration kinetic effects and complex particle-surface interactions. We studied the left branch of Paschen curve experimentally, analytically and by means of particle-in-cell/Monte Carlo collision (PIC/MCC) simulations for helium. A multi-valued Paschen curve in low voltage range 1kV and also in high voltage range 200kV was observed by experiments and predicted by PIC/MCC and analytical model [1, 2]. Three regimes of the breakdown have been identified according to contribution of impact ionization by electrons, by ions, and by fast neutrals to the total plasma generation. In the fast neutral and ion regime, the ionization avalanche is growing from the anode toward the cathode. Particles backscattering from the electrodes contribute the most to ionization near the anode and are responsible for initiating the ionization avalanche: fast neutrals backscattering from the cathode and fast electrons backscattering from the anode. [1] L. Xu et al. Phys. Plasmas 24, 093511 (2017). [2] L. Xu et al. Plasma Sources Sci. Technol. https://doi.org/10.1088/1361-6595/aace19 (2018).

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