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Spatio-temporal dynamics of pulsed gas breakdown in microgaps

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Microscale gas breakdown plays a critical role in microplasma generation for numerous applications and device lifetime for miniaturized electronics. This work provides further insight into the spatio-temporal dynamics of pulsed gas breakdown for different gap distances using an in-situ electrical-optical measurement method. Time-resolved sequential images and the corresponding photon number distributions are obtained to demonstrate the dynamic evolution of the breakdown channel morphology and the ionization intensity during breakdown development. For a 15 μm gap, breakdown transitions from a spot area on both electrode surfaces to a broad discharge region comprised of filamentary main breakdown channel (2.00 μm) and surrounding weak ionization area due to the local field enhancement. For a 2 μm gap, it transitions from a thin channel (1.09 μm) to a wider and uniform channel (2.14 μm) because the electric field is more uniform at smaller gaps. Interestingly, the main breakdown channel width at the instant of breakdown is independent of the gap width. For the 2 μm gap, field emission dominates the initial stage of breakdown and collision ionization (α process) dominates during breakdown development, while the Townsend avalanche dominates the breakdown process for the 15 μm gap. We apply a simple asymptotic theory to quantify the relative contribution of these phenomena and predict that breakdown will follow Paschen's law for gaps larger than 17.8 μm.

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