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Self-organized pattern formation in dielectric barrier discharge and kinetic simulations

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As an interesting type of gas discharges to generate low-temperature plasmas, the dielectric barrier discharge (DBD) is well known for its wide applications, such as UV sources, ozone generation and chemical reactors. Recently, increasing attention has been paid to DBD as a tool to study the nonlinear pattern formation. It is capable of producing the most varieties of patterns with very simple experimental setup. By using the special designed DBD system with two water electrodes, more than 40 kinds of patterns have been obtained in our system, including complex superlattices as shown in Fig. 1. These plasma patterns exhibit high spatial-temporal symmetries at the macroscopic level, while are characterized by complex dynamics and interactions in microscopic scale. These intriguing phenomena have motivated lots of interest in the underlying physics of DBDs.

Here we present both experimental and numerical studies of pattern formation in DBD. A variety of plasma structures have been obtained by changing different discharge parameters. Two-dimensional particle-in-cell simulations with Monte Carlo collisions included (PIC-MCC) have been performed. The evolution of two successive filamentary discharges within two half cycles of the applied voltage is studied as shown in Fig. 2. It is shown that the filamentary discharges involve the interplay between the external field, the surface charge field, and the space charge field. This leads to a few fine structures emerging, such as the weak discharge occurring at the zero-crossing point of the ac voltage, the splitting phenomenon of filaments, and the coexistence of positive and negative surface charges at footprints of the filamentary discharges. The formation of side discharges is also studied, which is supposed to be a key factor responsible for diversity and spatial-temporal symmetry breaking of pattern formation. It is found that the side discharges results from a joint action of both the transverse plasma diffusion and the ion induced secondary electron emission beyond the inhibition zone. The experimental observations and numerical simulation are in good agreement. Our results reveal the underlying physics governing the discharge and explain the dynamical behaviors of the DBD filaments. It may find wide applications in the fields such as material modifications, plasma photonic crystals and plasma biotechnology technologies.

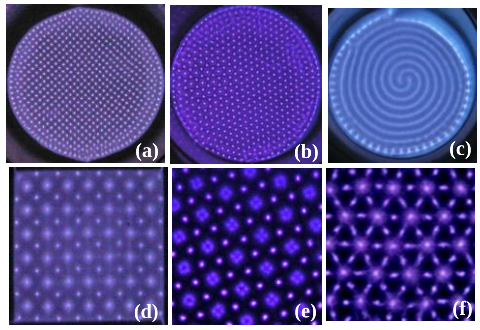
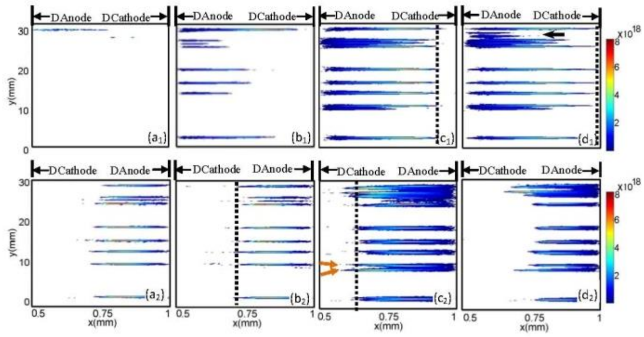


Fig. A rich variety of patterns observed in DBD with two water electrodes



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