Comparison of the energy transmission characteristics of Annular SDBD under AC and Nanosecond Pulsed Excitation

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Surface dielectric barrier discharge (SDBD) has demonstrated significant advantages in fields such as fluid control engineering. As a novel plasma generation structure, the energy transmission characteristics, characteristics of annular SDBD are influenced by the discharge mode and the excitation source. Different excitation sources, such as high-frequency alternating current power supply and nanosecond pulse power supply, exhibit significant differences in the aspect of energy transmission effects. This paper constructs an energy transmission characteristic shadowing device to systematically compare the energy transmission output characteristics and flow evolution differences of the annular SDBD under two different excitation methods.

Under the condition of nanosecond pulse excitation, the annular SDBD generates multiple shock waves and exhibits wall jet characteristics. Depending on the time scale, the energy transmission characteristics under nanosecond pulse excitation are divided into three stages: microsecond, millisecond and second.

At the microsecond level, due to the effect of nanosecond pulse excitation, the surface dielectric barrier discharge generates a strong instantaneous electric field. Within the discharge area, a large amount of energy accumulates rapidly in an extremely short period of time, causing the air temperature to rise sharply (approximately at the 2000 K level) and expand, forming a local high-pressure zone. The high-temperature and high-pressure gas expands outward at supersonic speed, compressing the surrounding air to form a shock wave (also known as a compression wave). The shock wave is composed of an arc wave and a plane wave. Its intensity increases as the voltage amplitude rises, while the frequency and the duration of the falling edge have no effect on the intensity of the shock wave.

During the millisecond period, as the shock wave continues to be generated and spreads, a negative pressure area is formed in the discharge region. The air above the dielectric surface is attracted and drawn in. Due to the obstruction of the dielectric, the airflow changes direction and begins to spread upwards, forming an airflow.

At the second stage, due to the diffusion and dissipation effects of the vortex structure, the momentum exchange in the flow field gradually becomes balanced, resulting in the formation of a jet structure along the wall surface on the medium surface.

The AC excitation generates a continuous ion wind through periodic discharges. After the peak-to-peak voltage reaches 14 kV, the ion wind converges to form a vertical upward turbulent structure accompanied by peripheral vortices. The formation of the turbulent and vortex structures is applicable for stable and sustainable energy transmission control. At the same time, both the increase in voltage and frequency can enhance the intensity of the airflow and the efficiency of momentum transfer efficiency.

References

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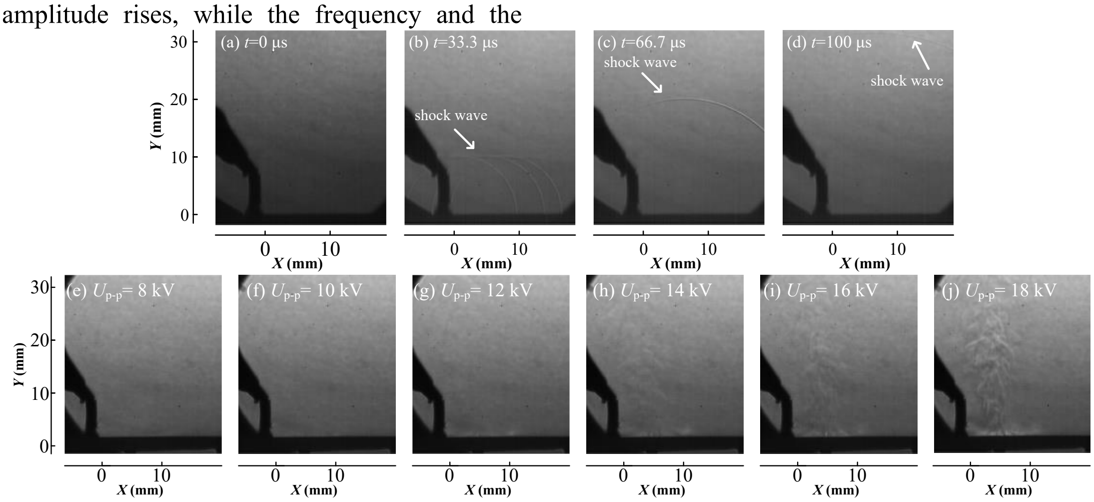

Figure 1. （a-d）The development and evolution process of shock waves under Nanosecond Pulse Excitation. （e-j）Variation of energy transmission characteristics under different voltage amplitude AC Excitation.