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Investigation on the electric-field driven ionization wave in nanosecond pulse discharge

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The breakdown process in gas discharge is generally accompanied by the propagation of ionization wave (IW), which is closely related to the local electric field [1]. In this work, a non-intrusive diagnostic method, electric field induced second harmonic (E-FISH), is introduced and its application for electric field measurement in nanosecond pulsed discharges with a good temporal and spatial resolution is presented. A brief review and comparison related to existing diagnostic methods for electric field are given firstly. The principle, experimental strategies, and influence factors of the E-FISH method are discussed. With nanosecond pulsed surface dielectric barrier discharge (SDBD) [2] and atmospheric pressure plasma jet (APPJ) [3] as examples, typical measurement results with E-FISH method are demonstrated.

Figure 1 shows electric field in APPJ with and without targets. With a dielectric target, it is obvious that a pronounced axial electric field (E_z) already exists before imposing HV pulse and its strength decays rapidly away from the dielectric target. The existence of this electric field shares the same mechanism of SDBD and is due to the residual surface charges on the dielectric left by the previous pulse. Similarly, an electrostatic probe verifies the existence of residual surface charges and its positive polarity (same as the HV polarity). Therefore, re-sidual surface charges generate an electric field in the opposite direction to that during IW propagation. Without a target, the velocity of the primary IW is slower compared with that with a target, which agrees with the temporally resolved discharge images. These is a distinguished difference related to the second E_z peak, i.e., the second E_z peak in free APPJ is the strongest near the nozzle, while it is stronger away from the nozzle with a target. In addition, the second E_z peak in free APPJ appears on the voltage falling edge, while the second E_z peak in APPJ with a target appears on the voltage plateau. In free APPJ (driven by positive HV), on the voltage rising edge, positive ions are left at the head of APPJ, where electrons are supplied under a reversed electric field on the voltage falling edge.

Based on the measured temporal and spatial evolution of electric field, it is found that ionization waves, driven by electric field, exist universally in different forms of pulsed discharges with distinguished appearances. Both space charges in volume and surface charges on dielectric will contribute to the measured electric field. With the existence of dielectric, residual surface charges generate retarding electric field in the opposite direction to that of ionization wave propagation. It is proposed that the E-FISH diagnostic can be extended to a wider range of applications.

References

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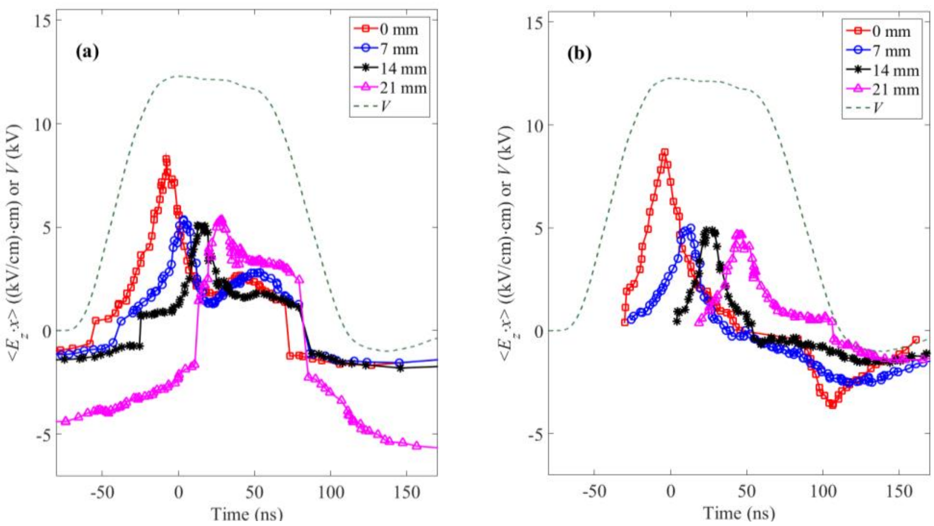

Figure 1 The evolution of $<E_z{\cdot}x>$ at different locations in the APPJ (a) with a Kapton dielectric target and (b) with no target (free APPJ). The peak voltage is ~ 12 kV. [3]