Pulsed Nano- and picosecond Discharge Development in Liquids

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Three possible mechanisms for the propagation of discharge in liquids play a different role depending on the pulse duration. The first case takes place when a "long" (microsecond) electric pulse applied in a non-conducting fluid: as a result of electrostatic repulsion, the formation of low density channels occurs. Consequently, the discharge propagates through the low-density regions [1]. In the second case, under an "intermediate" (nanosecond) electric pulse conditions, the electrostatic forces support the expansion of nanoscale voids behind the front of the ionization wave; in the wave front the extreme electric field provides a strong negative pressure in the dielectric fluid due to the presence of electrostriction forces, forming the initial micro-voids in the continuous medium [2, 3]. Finally, in the third case, when a "short" (picosecond) electric pulse is utilized, the regions of reduced density cannot form because of the extremely short duration of the applied electric pulse. Ionization in the liquid phase occurs as a result of direct electron impact without undergoing a phase transition, occurring due to the acceleration of electrons by an external electric field comparable to the intra-molecular fields. In this case, the discharge propagates with a velocity comparable to the local speed of light [4, 5].

The differences in the nanosecond discharge development in liquid dielectrics with different dielectric permittivity coefficients show a significant decrease in the breakdown threshold for discharge in water in comparison to that of hexane, which may be explained by the formation of micro-discontinuities in the media during the electrostriction compression/rarefaction stage, specifically in liquids with high dielectric permittivity coefficients. In two other cases – for “long” microsecond and “short” picosecond pulses – the dielectric permittivity of the liquid plays only a minor role for the discharge formation.

References

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