Electrical breakdown in pulsed electric field in water-oil system

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Development of electrical breakdown across the interface between water and transformer oil in a pulsed electric field is studied experimentally and by mathematical modeling. The discharge develops through the growth of a water cone in the oil towards the high-voltage electrode in the studied range of applied voltage, which is below oil breakdown voltage for a given layer thickness. Depending on water conductivity and amplitude of applied voltage and after the cone reaches the high-voltage electrode 1) electrical current can flow without plasma formation, 2) electrical current can cause plasma onset through thermal mechanism of breakdown, or 3) plasma channel can appear through the water droplets before the cone touches HV electrode due to water jet at the cone tip. At long pulse duration and voltages insufficient for short circuiting, the water cone occupies an equilibrium state somewhere inside the gap. Its height is independent of pulse duration and determined only by voltage amplitude. At voltages sufficient for gap closure, the closing time decreases sharply with increasing voltage. Such nonlinear behavior is attributed to the fact an electrostatic force originates from the spatial inhomogeneity of the Maxwellian stress tensor and is determined by the values of the second derivatives of the potential. The performed mathematical modeling showed the main part of this inhomogeneity occupies a thin layer the interface between two liquids. The force determined by the divergence of the Maxwell tensor is contributed by the spatial variation of the square of the electric field (energy density) rather than by the change in ε, although they are related. Thus, the thin layer where the force acts is not located in the middle of the interface as might be expected, but is above the area of the maximum ϕ and ε gradients — in the liquid with smaller ε.