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"LIQUID" NONEQUILIBRIUM PLASMA GENERATION IN WATER BY PULSED NANOSECOND DISCHARGE

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In most cases, the electric breakdown of liquids is initiated by the application of high electric field on the electrode, followed by rapid propagation and branching of plasma channels. Typically plasma is only considered to exist through the ionization of gases and typical production of plasmas in liquids has generated bubbles through heating or via cavitation and sustains the plasmas within those bubbles. The question appears: Is it possible to ionize the liquid without cracking and voids formation?

To answer this question we used a pulsed power system with +27 kV pulse amplitude, 12 ns pulse duration, 1 ns rise time. Discharge cell had point-to-plate geometry with a diameter of 100 μm. Inter-electrode distance was 3 mm, low-voltage electrode diameter 18 mm (Figure 1). The measurements were performed with the help of 4Picos ICCD camera and quartz lens. Camera field of view was 2.6×1.7 mm (Figure 1).

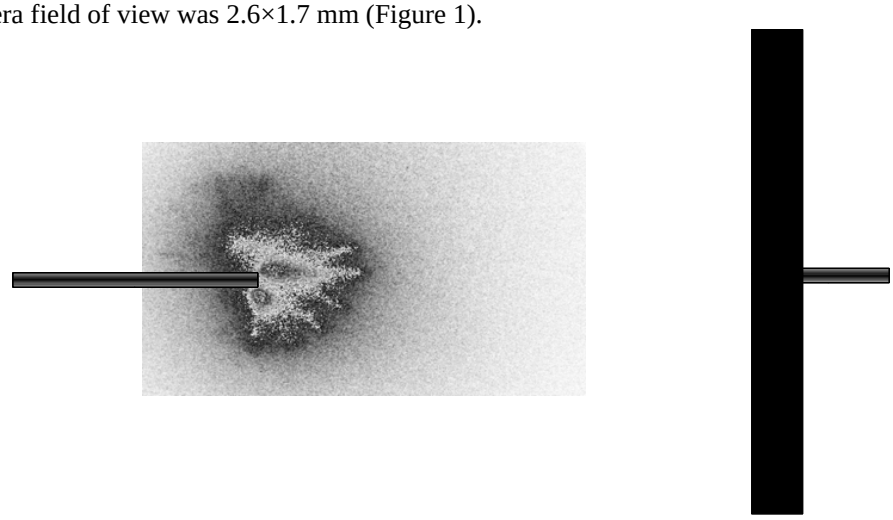

Figure 1. Geometry of discharge gap and ICCD camera field of view. Distilled water, U = 27 kV. Image was taken 5 ns after the pulse start. Camera gate is 1 ns.

It was found that discharge in liquid water develops in nanosecond time scale. Diameter of excited region near the tip of the high-voltage electrode was ~ 1 mm. The discharge demonstrates a typical streamer-type structure (Figure 1). No bubbling or void formation was observed. Thus the discharge observed has a completely different nature from the discharges initiated by electrical pulses with a longer rise time [1-4]. In [1] the pulses with 40 ns rise time and 18 kV amplitude demonstrate the velocity of discharge propagation about 2.5 km/s during the initial phase of the discharge. Both the shadowgraph and Schlieren images suggest that the branches are of gaseous nature [1].

In the case of short rise time we observed discharge propagation with the velocity up to 200 km/s (0.2 mm/ns) during very initial stage of the discharge corresponded to the voltage increase (Figure 2). Typical emitting channels diameter was ~ 50 μm and propagation length was 0.5-0.6

mm for U = 27 kV. When voltage reaches the maximum, the discharge stops and the "dark phase" appears (t = 6 – 9 ns in Figure 2). During this phase discharge cannot propagate because of space charge formation and electric field decrease. Voltage decrease on the high-voltage electrode leads to the reverse stroke formation and second emission region (Figure 2). This means that the channels lost the conductivity and the trailing edge of the nanosecond pulse generates significant electric field and excitation of the media. This effect proves that we have no voids formation or phase transition during the first stage of the discharge.

Thus we have demonstrated possibility of formation of nonequilibrium plasma in liquid phase without voids formation and investigated the dynamics of excitation and quenching of nonequilibrium plasma in liquid water.

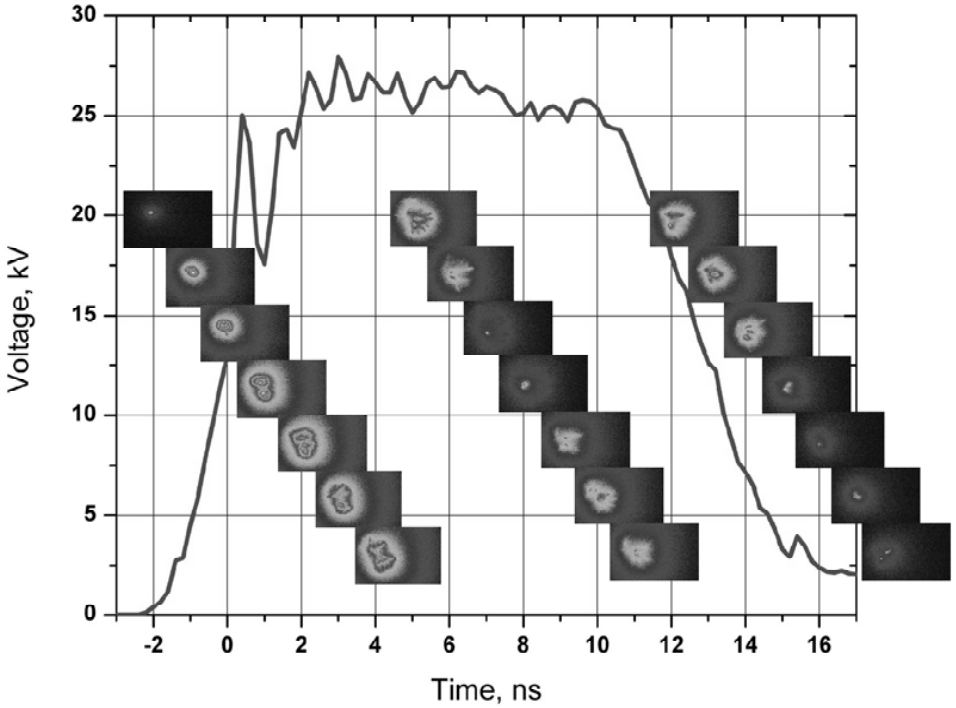

Figure 2. Dynamics of discharge emission and high-voltage potential on electrode. Distilled water, U = 27 kV. Camera gate is 1 ns. Spectral response 220-750 nm.

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