RESEARCHING OF ACOUSTIC WAVES IN PLASMA-LIQUID SYSTEM WITH PULSED DISCHARGE

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The research results of acoustic signals generation by microsecond pulse discharger in cylindrical plasma-liquid system are presented. It was investigated that the gas dissolved in liquid and the duration of electrolysis phase have influence on the amplitude of the acoustic signals. The cylinder radius and height were 135 and 10 mm respectively. Discharge was generated between two electrodes located on the cylinder axis.

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INTRODUCTION

Plasma chemistry consider plasma as a chemical active medium, which activity is provided by high temperatures and high concentrations of reactive components. The price for such high plasma activity is a low selectivity of plasma-chemical transformations.

The need for increasing the plasma chemistry selectivity becomes stronger by the transition from chemical industry to "green chemistry". The chemical yield effectiveness is evaluated at this new conception as the exclusion of hazardous waste and using of non-toxic substances [1].

The processes in supercritical fluids have perspectives in motion towards green chemistry. Water mixes unlimitedly in supercritical condition with oxygen, hydrogen and hydrocarbons, facilitating their interaction with each other – oxidation reactions are very fast in supercritical water (H_2O_{sc}). One of the most interesting supercritical water applications is effective chemical warfare agents decomposition [2]. These supercritical conditions in liquids can be created in plasma-liquid systems with pulsed discharge. The pulsed electrical discharge in the liquid comes up with new related factors: strong ultraviolet radiation and presence of acoustic or shock waves. In addition, acoustic oscillations can be used in such systems as an additional mechanism of action for chemical transformations.

Perhaps the most promising method of using acoustic waves is their generation by axial pulsed electric discharge with following reflection from a perfect cylindrical surface, which can provide better compression symmetry for convergent acoustic waves, in the gas and liquid phases. This work is devoted to such approach investigation.

1. EXPERIMENTAL SET-UP

The experimental set-up schematic in Fig. 1 is shown. The main part of the system is cylinder with height H = 10 mm and radius R = 135 mm. The cylinder is filled with distilled water (1) as a working liquid. The electrodes (2) are placed perpendicular to the cylinder axis. These electrodes are made of copper with diameter 10 mm and have the conical shape. Discharge (3) between electrodes is ignited. The piezoceramic pressure sensor (4) is installed at 40 mm distance from the cylinder lateral surface and registers acoustic wave formed due to electric discharge. The cylinder (5) wall thickness is 50 mm.

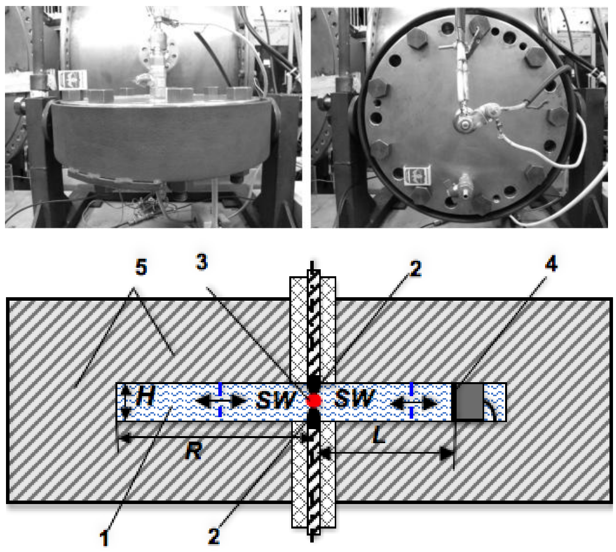

Fig. 1. Plasma-liquid system with a pulse discharge: 1 – liquid; 2 – electrodes; 3 – discharge; 4 – piezoceramic pressure sensor; 5 – cylinder wall

Researches were carried out for discharge current and acoustic signal (first and second reflected acoustic waves) depending on accumulated energy in the capacitor, the angle of system inclination and gas presence in the liquid.

Capacitor bank has a constant capacitance of C = 67.5 nF. The charged capacitor energy was varied by charging voltage. Voltage varied in the range from 20 to 70 kV. Energy changed in range from 13.5 to 165 J respectively. The Rogowski coil for current measuring was used. In each experiment 6 measurements for statistics were performed.

2. RESULTS AND DISCUSSION

The electrolysis phase is always presented in plasma-liquid systems during pulsed discharges study. If this phase is continued long enough the most energy is dissipated, so the energy per pulse is reduced. This leads to the fact that the second acoustic signal wave diverging significantly less than the first and the amplitude of the first acoustic wave becomes smaller.

The long electrolysis phase duration is, probably, due to the large electrodes surface contact with liquid. Duration of electrolysis phase also depends on the liquid conductivity and dissolved gases in it. The performed research deals with these factors impact on acoustic signals which is generated in the system (convergent and divergent acoustic waves).

The conical shape electrodes were used for reducing of surface contact with liquid. The increasing of distance between the electrodes is also possible at this condition. The discharge current and the acoustic signal forms for these electrodes are shown at Fig. 2 (the distance between the electrodes is 1.5 mm, the capacitor voltage is 35 kV).

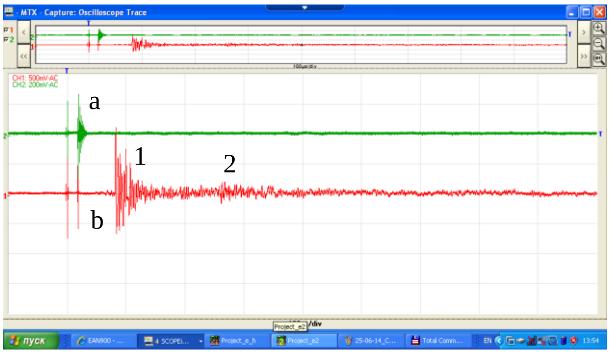

Fig. 2. Oscillograms of current (a) and acoustic signal (b) (1 – first divergent acoustic wave; 2 – second divergent acoustic wave), d = 1.5 mm, U = 35 kV, C = 67.5 nF, distillate, cylinder positioned an angle 67°

Electrodes geometry change gave results. The electrolysis phase duration became commensurate to the current pulse duration (less energy is dissipated uselessly). But the second divergent acoustic wave amplitude remained small.

The usage of distilled water as a working liquid with a low content of dissolved gases was next step for increasing the amplitude of the second acoustic wave. The discharge current and the acoustic signal forms are shown on Fig. 3 for cone shape electrodes and distilled water with a low content of dissolved gases. Distance between electrodes – 1.5 mm, the capacitor voltage – 35 kV.

Using the distilled water with a low content of dissolved gases was able to get a second acoustic splash with larger amplitude. However, the amplitude of the second acoustic wave is still smaller than the amplitude of the first one.

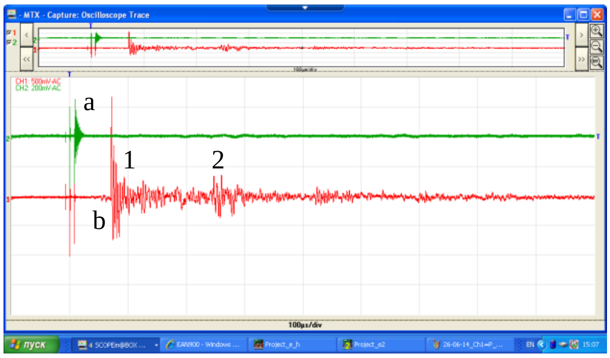

Fig. 3. Oscillograms of current (a) and acoustic signal (b) (1 – first divergent acoustic wave; 2 – second divergent acoustic wave), d = 1.5 mm, U = 35 kV, C = 67.5 nF, distilled water with a low content of dissolved gases, cylinder positioned an angle 67°

This can be explained by the fact that large amount of gas is released during the generation of pulsed discharges in plasma-liquid systems. The first convergent and second divergent acoustic waves propagation front is discomposed by this gas. As a result, the amplitude of the second acoustic wave is less than the first one.

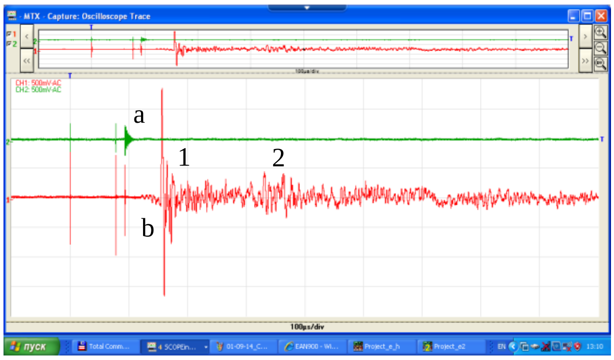

Fig. 4. Oscillograms of current (a) and acoustic signal (b) (1 – first divergent acoustic wave; 2 – second divergent acoustic wave), d = 1.5 mm, U = 40 kV, C = 67.5 nF, distilled water with a low content of dissolved gases, cylinder in a horizontal position

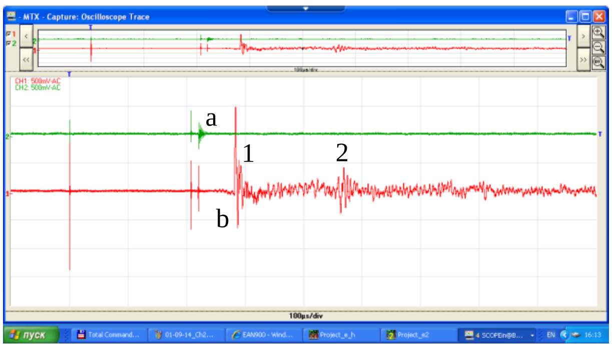

Fig. 5. Oscillograms of current (a) and acoustic signal (b) (1 – first divergent acoustic wave; 2 − second divergent acoustic wave), d = 1.5 mm, U = 40 kV, C = 67.5 nF, distilled water with a low content of dissolved gases, cylinder positioned an angle 45°

To avoid the negative impact of the gas produced in the system the approach to come it out have to be used. First experiments were carried out at 67° system inclination angle to avoid the cavities with air when system was filled by liquid. The series of experiments were carried out to determine the optimum inclination angle and provide the best outlet for generated gas. Measuring was carried out (Figs. 4-6) for acoustic signals in the plasma-liquid system of cylindrical geometry depending on the system inclination angle.

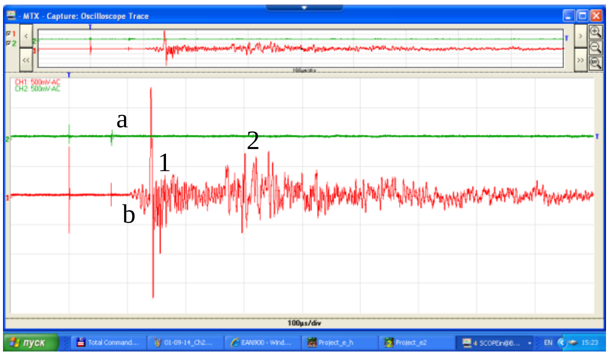

Fig.6. Oscillograms of current (a) and acoustic signal (b) (1 – first divergent acoustic wave; 2 – second divergent acoustic wave), d = 1.5 mm, U = 40 kV, C = 67.5 nF, distillate with a low content of dissolved gases, cylinder positioned an angle 90°

Current and acoustic signals oscillograms were measured at 40 kV charging voltage and distance between electrodes of 1.5 mm. It is clear from the presented results that the largest amplitude of the second divergent acoustic wave is reached at a vertical location of the cylindrical system. At such system position there was a possibly to obtain the amplitude of the second acoustic wave even bigger than the amplitude of the first acoustic wave.

CONCLUSIONS

1. Electrolysis does not influence on amplitude of the divergent acoustic waves if electrolysis phase duration is comparable to current pulse duration.
2. The first and second acoustic wave amplitudes are the same when distilled water with a low content of dissolved gases is used as working liquid and plasma-liquid system with cylindrical geometry has the vertical position.

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ИССЛЕДОВАНИЕ АКУСТИЧЕСКИХ ВОЛН В ПЛАЗМЕННО-ЖИДКОСТНОЙ СИСТЕМЕ С ИМПУЛЬСНЫМ РАЗРЯДОМ

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Представлены результаты исследования генерации акустических сигналов импульсным разрядом микросекундной длительности в плазменно-жидкостной системе цилиндрической геометрии. Исследовалось влияние газа в жидкости и длительности фазы электролиза на амплитуду акустических сигналов. Радиус цилиндра 135 мм, высота 10 мм. Разряд генерировался между двумя электродами, расположенными на оси цилиндра.

ДОСЛІДЖЕННЯ АКУСТИЧНИХ ХВИЛЬ В ПЛАЗМОВО-РІДИННІЙ СИСТЕМІ З ІМПУЛЬСНИМ РОЗРЯДОМ

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Представлено результати дослідження генерації акустичних сигналів імпульсним розрядом мікросекундної тривалості в плазмово-рідинній системі циліндричної геометрії. Досліджувався вплив газу в рідині та тривалості фази електролізу на амплітуду акустичних сигналів. Радіус циліндру 135 мм, висота 10 мм. Розряд генерувався між двома електродами, розташованими на вісі циліндру.