THE RESEARCH OF DOUBLE-PULSE DISCHARGE IN A PLASMA-LIQUID SYSTEM WITH CYLINDRICAL GEOMETRY

V.Ya. Chernyak[1], S.M. Sidoruk[1], V.V. Yukhymenko[1], V.E .Marchuk[2], E.V. Martysh[1], O.A. Fedorovich[3], V.O. Andryuschenko[1]

[1]Taras Shevchenko Kiev National University,
E-mail: chernyak_v@ukr.net;
[2]PAS "KVAZAR", Kiev, Ukraine;
[3]Institute of Nuclear Research, National Academy of Sciences of Ukraine

The results of acoustic signals generation by two consistent dischargers of microsecond duration in a cylindrical liquid system are presented. The radius/height ratio of the cylinder, made of stainless steel, is ~ 13.5. Both discharges occur between two electrodes located on the cylinder axis. Height of the cylinder / interelectrode distance ratio is 13.5. The delay time between the discharges has been regulated and changed in a broad spectrum: before and after the axial collapse of the cylindrical converging wave reflected from the wall. The switches were: the air discharger for the first discharge and hydrogen thyratron for the second one.

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INTRODUCTION

Plasma chemistry of XX century considered plasma as a chemical active medium, which activity is provided by high temperatures and high concentrations of reactive components: ions, electrons, radicals, excited particles, and photons. The price for such high activity of plasma is a low selectivity of plasma-chemical transformations, i.e. the multi-channel passing of chemical reactions and weak control of this process. Traditional way of increasing a plasma-chemical selectivity is transferring from thermal to non-equilibrium plasma.

Today, the need to increase the selectivity of the plasma chemistry become stronge by the transition of the chemical industry to "green chemistry". "Green Chemistry" is a departure from the traditional concept of evaluating the effectiveness of the chemical yield to the concept that evaluates the cost-effectiveness as the exclusion of hazardous waste and non-toxic and / or hazardous substances [1].

A quantitative measure of the environmental acceptability of chemical technology is the factor of E [1], which is defined as the ratio of the mass of waste (waste) to the mass of principal product. Waste is all that is not the principal product.

Perspectives towards green chemistry have processes in supercritical fluids (water, carbon dioxide). Water in supercritical condition unlimited mixes with oxygen, hydrogen and hydrocarbons, facilitating their interaction with each other - oxidation reaction are very fast in scH2O. For example, in supercritical water significantly increases the rate of oxidation, such as the use of water can be not only effective destruction of hazardous chemical substances, but also hydrolysis, hydration, formation or degradation of carbon-carbon bonds, and so on. One of the most interesting uses of the supercritical water - effectively destroying chemical warfare agents [2]. Robert W. Shaw-CB MTS IV (2002)].

The main problem that hinders the introduction of technologies with supercritical water - it's pretty high cost industrial units, working under high pressure: they need heat-resistant alloys and special railing, which eliminates the possibility of explosions reactors. In addition, scH_2O - aggressive environment, it causes corrosion of parts.

Implementation conditions supercritical liquid in collapse convergent acoustic waves can be a solution to the problem of extreme aggressiveness scH_2O. In this case reactor walls are in contact with less agressive to critical liquid.

1. EXPERIMENTAL SET-UP

Plasma chemical reactors with cylindrical geometry and discharge plasma axial location created on the condition that the characteristic radius of the plasma channel - r was much smaller than the radius of the cylinderical reactor R. The cylinder radius was much larger than the cylinder height – H: R/H = 13.5. Schemes of plasma chemical reactors are represented on Fig. 1.

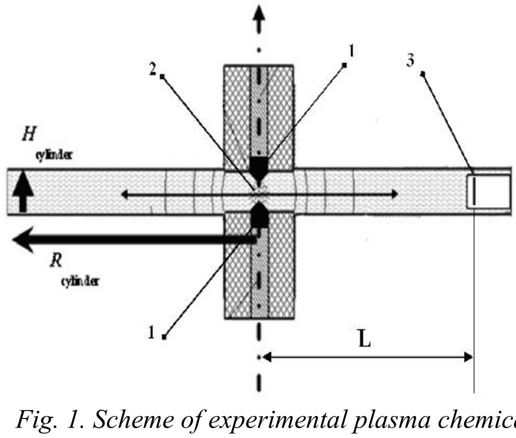

Fig. 1. Scheme of experimental plasma chemical reactor. 1 — copper electrodes, 2 — discharge plasma, 3 — piezoceramic pressure sensor

The outer diameter of the cylinder, made of stainless steel was 370 mm and 270 mm was internal one. Pressure sensor located inside the cylinder perpendicularly to radius on distance from an axis L Two coaxial electrodes are made of stainless steel with copper tips -1 (Fig. 1). and hermetically bringing in teflon insulator closing in the liquid volume to form a discharge gap. Diameter of electrode copper tips was 10 mm. Discharge gap length (d) at which the steady breakdown in the liquid occurs was 0.25…0.5 mm at the voltage of ≤ 19 kV.

The main feature of electrical scheme for pulsed power feeding of discharge in a liquid is usage of two independent capacitors (C_1, C_2) which are supplied two independent sources of power. Pulsed discharge realized in two modes: single and double pulses. In the single pulse mode only one capacitor is discharged.

Double pulse mode is realized as follows: one capacitor discharges in the interelectrode gap through air spark gap; the clock signal from the Rogowski belt after first breakdown is applied to the thyratron circuit and second capacitor discharges through it. This set of events leads to the second breakdown of the discharge gap and second discharge appearance.

Delay of the second discharge ignition (t_d) may be changed in range of 50…300 mcs (collapse of the converging wave corresponds to the time delay ~ 180 mcs). The following parameters are measured: discharge current and the signal from the pressure sensor. The signal of the Rogowski belt is recorded with an oscilloscope.

Optical investigations were made by recording the emission of plasma channel that passes through the special quartz window.

2. RESULTS

Typical oscillogrammes of the acoustic signal and discharge current in such system at ballast resistance R_{balast}=0 in mode of single pulse are presented in Fig. 2. On the Fig. 2: 1 is the acoustic signal for the first divergent acoustic wave; 2 – first convergent acoustic wave; 3 – second divergent acoustic wave; 4 –second convergent acoustic wave.

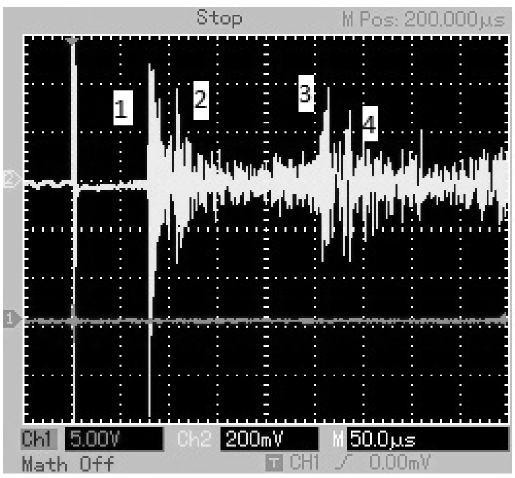

Fig. 2. Oscillogrammes of current (gray) and acoustic signal (white) in mode of single pulse. R_{balast}=0 Ohm, L=11.5 cm

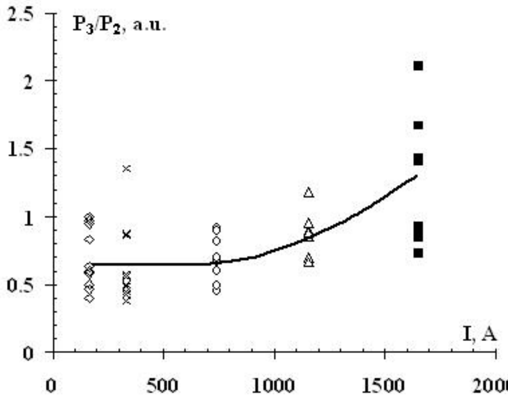

Fig.3. The dependence of the ratio of the amplitude of the second divergent wave (3) to the amplitude of the first convergent wave (2) on the pulse curren

Typical oscillogrammes of the acoustic signal and discharge current in such system at ballast resistance R_{balast}=0 in mode of double pulses are presented in Fig. 4.

In double pulse mode (the second pulse discharge occurs in collapse of a converging shock wave, generated by the first pulse discharge), the first discharge is realized in a narrow gas channel with a radius comparable to the size of the plasma channel. The second discharge is realized in a wide gas channel with a radius that exceeds the size of the plasma channel.

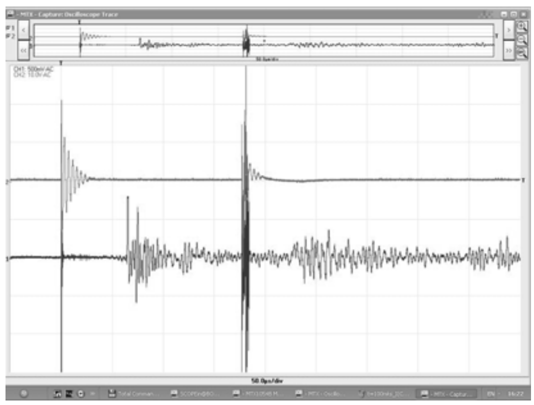

Fig. 4. Oscillogrammes of current (gray) and acoustic signal (black) in mode of single pulse. d=0.25 mm, R_{balast}=0 ohms, L=9.5 cm, t_d=181 mcs, C_1=C_2=105 nF

The research of ethanol reforming in pulse plasma-liquid system has shown, that the transition from one-pulse mode to double-pulse mode is accompanied by reduction syn-gase ratio ($[H_2]/[CO]$).

CONCLUSIONS

In double pulse mode, the first discharge is realized in a narrow gas channel with a radius comparable to the size of the plasma channel.

The second discharge is realized in a wide gas channel with a radius that exceeds the size of the plasma channel.

Nonlinear dependence of the ratio of the amplitude of the second divergent wave to the amplitude of the first converging wave from the discharge current was shown.

ACNOWLEDGEMENTS

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ИССЛЕДОВАНИЕ ДВОЙНОГО ИМПУЛЬСНОГО РАЗРЯДА В ПЛАЗМЕННО-ЖИДКОСТНОЙ СИСТЕМЕ С ЦИЛИНДРИЧЕСКОЙ ГЕОМЕТРИЕЙ

В.Я. Черняк, С.Н. Сидорук, В.В. Юхименко, В.Є. Марчук, Е.В. Мартыш, О.А. Федорович, В.А. Андрющенко

Представлены результаты исследований генерации акустических сигналов двумя последовательными разрядами микросекундной длительности в цилиндрической жидкостной системе. Отношение радиуса к высоте цилиндра из нержавеющей стали составляло ~ 13,5. Оба разряда происходили между двумя електродами, расположенными на оси цилиндра. Отношение высоты цилиндра к межэлектродному расстоянию было >10. Время задержки между разрядами могло изменяться в широком диапазоне: до и после коллапса на оси сходящейся цилиндрической акустической волны, отраженной от металлической цилиндрической стенки. В качестве коммутаторов разрядов использовались воздушный разрядник для первого разряда и водородный тиратрон для второго.

ДОСЛІДЖЕННЯ ПОДВІЙНОГО ІМПУЛЬСНОГО РОЗРЯДУ В ПЛАЗМОВО-РІДИННІЙ СИСТЕМІ З ЦИЛІНДРИЧНОЮ ГЕОМЕТРІЄЮ

В.Я. Черняк, С.Н. Сидорук, В.В. Юхименко, В.Є. Марчук, Є.В. Мартиш, О.А. Федорович, В.А. Андрющенко

Представлено результати досліджень генерації акустичних сигналів двома послідовними розрядами мікросекундної тривалості в циліндричній рідинній системі. Відношення радіуса до висоти циліндра з нержавіючої сталі становило ~ 13,5. Обидва розряди відбувалися між двома електродами, розташованими на осі циліндра. Відношення висоти циліндра до міжелектродної відстані було > 10. Час затримки між розрядами міг змінюватися в широкому діапазоні: до і після колапсу на осі збіжної циліндричної акустичної хвилі, відбитої від металевої циліндричної стінки. В якості комутаторів розрядів використовувалися повітряний розрядник для першого розряду і водневий тиратрон для другого.