Effect of non-thermal plasma electrical parameters on hydrogen peroxide generation in pulse gliding arc mini-reactors

R. Burlica[1], R. Wendell[2] and B. R. Locke[2]

[1] "Gheorghe Asachi" Technical University of Iasi, Faculty of Electrical Engineering, Blvd. D. Mangeron nr. 25, Iași 700055, Romania

[2] Florida State University, 2525, Pottsdamer St., Tallahassee 32310, Florida, USA

In the present work the effects of electrical parameters of the plasma on hydrogen peroxide formed with liquid water, for different liquid flow rates, in an asymmetrical electrode mini-gliding arc reactor are studied. The cylindrical glass reactor of 2 mL volume is equipped with two divergent wire electrodes supplied by a pulsed (glidarc) electrical discharge. The formation rates and energy yields of H_2O_2 generated in in the plasma from pure water exposed to a non-thermal pulsed plasma-gliding arc reactor equipped with a spray nozzle have been studied. Previous work showed that spraying the liquid through a special two-way nozzle directly into the plasma zone is an effective method to enhance the efficiency of chemical species formation in gliding arc reactors and the present work shows high efficiency for the mini-reactor. The formation rates of hydrogen peroxide were determined, emphasizing the variation of energy efficiency with electrical power, frequency and water flow rate.

1. Introduction

Cold plasma technologies have proven to be effective in the degradation of organic compounds dissolved in water and in the conversion of various organic compounds into syngas or molecular hydrogen. Non-thermal plasma (NTP) is produced by an electrical discharge under special conditions in order to avoid the transition to thermal plasma. NTP generates highly energetic species in the plasma phase (electrons, ions, excited atoms and molecules) at low gas temperature (room temperature) and atmospheric pressure, [1], [2]. The active species formed at the interfaces of a plasma channel and gas and liquid phases interact with water molecules to generate highly oxidative chemical oxidation leading to the formation of OH radicals, hydrogen peroxide and nitrogen species (if air is using as working gas). The gliding arc reactor used here generates plasmas in a glass tube, with cylindrical or custom shaped geometry, by a pulsed high voltage electric discharge developed in a gas flowing between two divergent electrodes, in order to provide the physical conditions required of non-thermal plasma evolution. The electrical discharge generates a plasma channel that increases its length due to the gas flow directed along the electrodes and at the same time its temperature decreases, until the plasma channel breaks into quenched plasma cloud. It is known that the efficiency of production of chemical active species in water exposed to a gliding arc depends on the gas-liquid interfacial contact area between the liquid treated and the plasma zone (therefore the water was spraying directly into the plasma zone, through a special two-way nozzle), [3].

In order to enhance the gliding arc efficiency by increasing the contact between the plasma and water droplets, the plasma is produced in a narrow chamber in order to confine the plasma and force the water droplets to contact the plasma species. In addition, the electrodes are supplied by a high voltage pulsed power supply in order to increase the reactor efficiency by increasing the specific energy yield, [4], [5].

2. Experimental

The gliding arc reactor consists in two stainless steel

The gliding arc reactor consists of two stainless steel diverging wire shape electrodes attached to a cylindrical glass tube support, which form a narrow chamber (about 2 mL) where the reactions between plasma and liquid take place. The reactor schematic and the appearance of the discharge are shown in Fig. 1. The sample solution is directly sprayed into the plasma formed between the electrodes, by a high pressure pump, through a two-port injection nozzle, one port for the gas injection and the other for the liquid. The water is carried along by the gas flow through the outlet port and it is atomized due to the high velocity of the gas. The electrodes are supplied by a pulsed HV power supply (auto ignition coil).

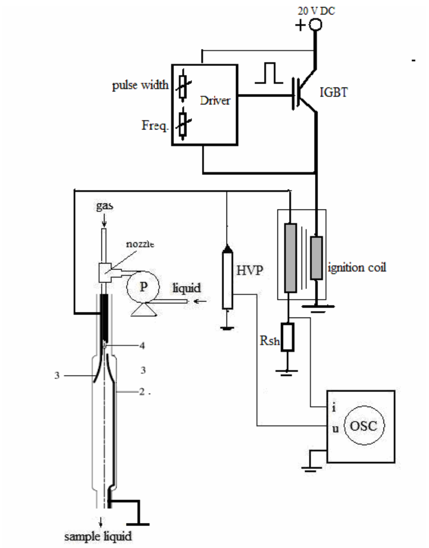

Fig.1 The glidarc mini reactor. 1- outlet, 2- inner ground electrode, 3- upper electrode, 4 – reactor inlet, 5- two way nozzle, 6- vessel, HVP-high voltage probe, R_{sh}- shunt

The power of the discharge was calculated from average values of the voltage and the current measurements on the reactor electrodes, measured with an oscilloscope, (OSC).

The H_2O_2 formed in the liquid phase was measured using a colorimetric test with a Perkin-Elmer Lambda 3A UV Spectrophotometer.

The H_2O_2 energy yield was calculated by

$$EER(H_2O_2) = \frac{[H_2O_2]M_{H2O2}3.6}{P} \text{ [g/kWh]} \quad (1)$$

where $[H_2O_2]$ is the hydrogen peroxide production rate (μmoles/sec), M_{H2O2} is hydrogen peroxide molecular mass [g/mole] and P is the power [W].

3. Results and discussions

The water sprayed into the plasma zone in the confined space between the electrodes, is exposed to an intense interaction with the electronic and ionic species from plasma leading to the formation of chemically active species. H_2O_2 may form through an overall reaction such as:

$$2H_2O \rightarrow H_2O_2 + H_2 \quad (2)$$

Reactions between hydrogen peroxide and OH radicals take place:

$$H_2O_2 + OH \rightarrow HO_2 + H_2O \quad (3)$$

$$HO_2 + OH \rightarrow H_2O + O_2. \quad (4)$$

The maximum values of concentration of H_2O_2 in the liquid phase and energy efficiency yield for water flow rate and the electrical power of discharge are shown in Table 1.

Table 1. Concentration of H_2O_2 in the liquid phase and energy efficiency yield

		Q_w (mL/min)	P (W)
max. concentration of H_2O_2 (mM)	2.3 mM	2mL/min	0.5 W
max.H_2O_2 energy production yield	48 g/kWh	15 mL/min	0.1 W

The highest concentration of H_2O_2, 2.3 mM was found for the power 0.5 W (2 mL/min water flow rate) for Q_g=5L/min gas flow rate Ar. The maximum value for H_2O_2 energy production yield was 48 g/kWh, for Q_w = 15 mL/min, P=0.1 W.

4. Conclusions

The hydrogen peroxide concentration produced in water treated in the confined space between the electrodes in a mini-gliding arc reactor depends mainly on the power injected in the discharge and the gas flow rate.

The cylindrical gliding arc reactor presented offers also the possibility to scale up the system to a prototype scale using numerous mini-reactors supplied by low power high voltage pulses.

5. References

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