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Modeling of the Mechanism of Generating Processes of Water Electrolysis and Photosynthesis with Solar Energy Used for Productions of Gas Oxygen and Hydrogen, of Concentrate of the High-calorie Microalgae *Chlorella*, and for Industrial Wastewater Treatment

M. Shoikhedbrod[1,*]

Abstract

The use of solar energy for generation of the process of water electrolysis, permitting the oxygen and hydrogen gases production, concentration of the high-calorie fast productive ***Chlorella*** *microalgae, and industrial wastewater treatment is the most promising direction today. This is explained by the complete absence of electrical energy consumption for the implementation of these industrial technological projects. No less interesting is the process of photosynthesis of phytoplankton cells, which also allows, with the help of solar energy, to the phytoplankton cells of the world's oceans to utilize atmospheric carbon dioxide, reducing greenhouse gas emissions, and enrich it with oxygen. The main source of conversion of solar energy into electrical energy is a silicon semiconductor using strong special additives. The main source of conversion of solar energy into the biological activity of phytoplankton cells is the photosynthetic apparatus of phytoplankton cells - chlorophyll. The article presents molecular modeling of the mechanism of generation of the processes of water electrolysis and photosynthesis of microalgae cells by solar energy, permitting to carry out, developed by the author: the treatment of industrial wastewater; the concentration of high-calorie, fast-productive microalgae* ***Chlorella****; the production of gas oxygen and hydrogen.*

Keywords: Solar energy; oxygen and hydrogen gases production; conversion solar energy into electrical energy; conversion of solar energy into biological activity; electrolysis; photosynthesis.

INTRODUCTION

***Author for Correspondence**
M. Shoikhedbrod
E-mail: michaelshoikhedbrod@bell.net

[1]Active Director, Electromagnetic Impulse Inc., 21 Four Winds Drive, Unit 12, North York, Ontario M3J 1K7, Canada

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The use of solar energy for generation of the process of water electrolysis, permitting the oxygen and hydrogen gases production, concentration of the high-calorie fast productive ***Chlorella*** microalgae, and industrial wastewater treatment is the most promising direction today.

This is explained by the complete absence of electrical energy consumption for the implementation of these industrial technological projects.

The main source of converting solar energy into electrical energy and generating water electrolysis is a silicon semiconductor.

The silicon semiconductor has four electrons in its outer layer (Figure 1).

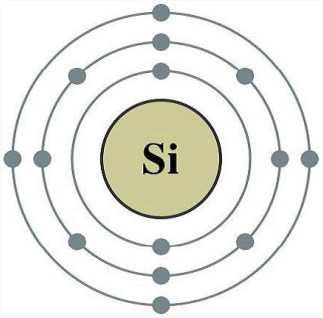


Figure 1. The silicon atom structure.

In practice, doped silicon with special additives is more often used.

Such additives are phosphorus and boron atoms due to their electronic structure: phosphorus has five electrons in its outer orbit, and boron has three.

Silicon, doped with phosphorus, having four electrons in the outer orbit, when combined with phosphorus, acquires an additional five electrons and, thus, there will be nine electrons in the outer joint orbit of silicon and phosphorus and, therefore, one unpaired electron will be extra, which doped silicon can with easy to release under external influence, since the total number of electrons in the outer joint orbit of silicon and boron should be eight.

Silicon, doped with boron, has the reverse situation: to the four electrons of silicon in the common outer orbit with boron, only three electrons of boron are added, and, thus, there will be seven electrons in the common orbit instead of eight and, therefore, one vacant site, called a “hole” is formed, capable of attracting electron to itself.

Depending on the use of two joint layers of silicon, doped with phosphorus and boron, or one layer silicon, doped with phosphorus, installations that convert solar energy into direct current electrical energy with subsequent generation of water electrolysis are divided into: photo module solar cells of solar panel and photoelectrochemical cell.

The solar panel [1–3] is multi-layered: a simple tempered protective glass, an anti-reflective sputtered layer, a solar photocell module layer made of solar cells, an EVA layer, an insulating layer and a connection block, which help to collect the maximum number of photons of sunlight into the panel (Figure 2).

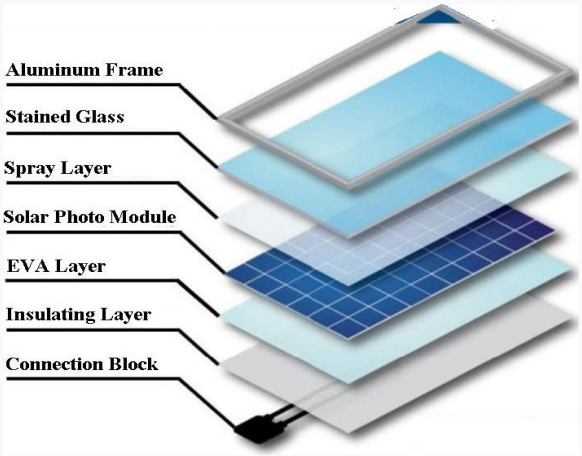


Figure 2. Structure of solar panel.

Olar panel work on the basis of special solar photo module, including solar cells from two joint layers silicon, doped with phosphorus and boron that capture solar energy and convert it into direct current electrical energy with subsequent generation of water electrolysis.

In a photoelectrochemical cell [4–7] - a layer of silicon semiconductor, doped with phosphorus, with an attached mesh anode, immersed in an aqueous solution of electrolyte, due to the influence of two photons of light, two electrons are “knocked out”, becoming a source of direct electric current that passes through the electrolyte with two electrodes, immersed in it, generates the electrolysis process.

No less interesting is the process of photosynthesis of phytoplankton cells [8-10], which also allows, with the help of solar energy, to the phytoplankton cells of the world's oceans to utilize atmospheric carbon dioxide, reducing greenhouse gas emissions, and enrich it with oxygen.

The main source of conversion of solar energy into the biological activity of phytoplankton cells is the photosynthetic apparatus of phytoplankton cells - chlorophyll.

The article presents molecular modeling of the mechanism of generation of the processes of water electrolysis and photosynthesis of microalgae cells by solar energy, permitting to carry out, developed by the author: the production of gas oxygen and hydrogen, the concentration of high-calorie, fast-productive microalgae ***Chlorella***, as well as the treatment of industrial wastewater.

Materials

As materials the water, industrial wastewater and microalgae ***Chlorella*** cells served.

Method and Developed Devices

Solar panel work on the basis of special solar photo module, including solar cells that capture solar energy and convert it into the electric current with the help of semiconductor devices.

The solar cell consists of two joint layers of silicon, doped with phosphorus, which has four electrons on the outer orbit and, when combined with phosphorus, acquires five more electrons and, thus, there will be nine electrons in the outer joint orbit of silicon and, therefore, one unpaired electron will be extra, easily separated from doped silicon under external influences, since the total number of electrons in the outer joint orbit of silicon and phosphorus should be eight (N-type (negative) layer of silicon) and doped with boron, which has four electrons in the outer orbit and when combined with boron, only three boron electrons are added, and thus there will be seven electrons in the total outer orbit instead of eight and, therefore, one vacant site, called a “hole,” is vacated (P-type (positive) layer of silicon).

The molecular model of the mechanism of generating of the water electrolysis process using a solar cell of a solar panel, powered by solar energy, is as follows.

When a solar cell of a solar panel is exposed by a solar ray, the “extra” electrons of the N-type silicon layer, due to their proximity to the “holes,” begin to combine through the N-P junction with the “holes” of the P-type silicon layer.

As a result, the border region of the N-type layer, due to the fact that a small part of the electrons goes into the region of the P-type layer, turns out to be partially positively charged, and most of the electrons “knocked out” by solar energy in the N-type layer move freely throughout the entire N-type layer.

The P-type boundary region turns out to be partially negatively charged, while the majority of unoccupied “holes” move freely in the general region of P-type layer of the layer (Figure 3).

If electrodes (cathode and anode) are connected to the outer N-type layer and the following outer P-type layer, then two oppositely charged poles will appear on the electrodes: minus on the cathode, plus on the anode, which will lead to the creation of a potential difference.

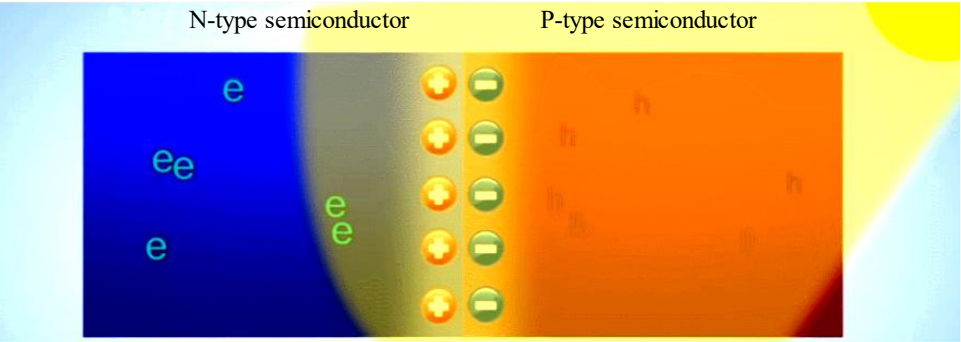


Figure 3. The electron-hole P-N junction and electrons "knocked out" by solar energy move freely in the common N-type region, and unoccupied holes move freely in the common P-type region.

If the electrodes are connected to an electrical circuit, the load of which will be, for example, a developed electroflotator for the treatment of industrial wastewater [11], then in the process of the flow of direct electric current through the wastewater between the electrodes, the process of electrolysis of wastewater in the electroflotator is generated, which plays a major role in the treatment of industrial wastewater (Figure 4).

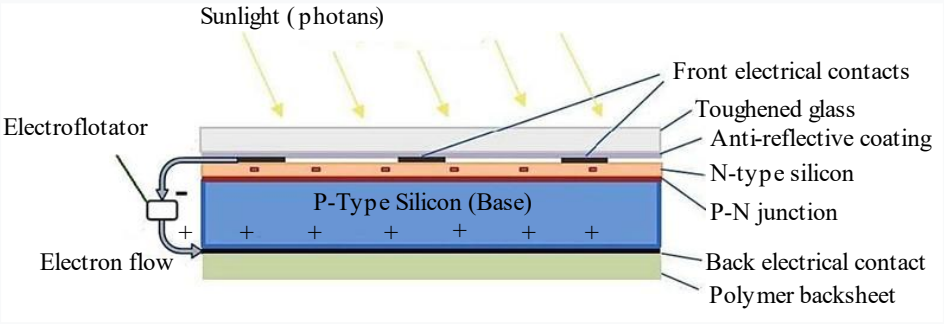


Figure 4. Solar cell operation.

Figure 5 schematically depicts the design of the developed electroflotator, powered by a solar cell and the principle of its operation in the process of industrial wastewater treatment. Structurally, a developed electroflotator for the continuous treatment of industrial wastewater, powered by direct electric current from a solar cell through electrodes -1, connecting the negative electrode of the N-type silicon semiconductor layer -2 with the cathode terminal of the electroflotator, located on a special plug device, connecting the external terminals to the electrodes of the electroflotator and the positive electrode of the P-type silicon semiconductor layer -3, has a flotation chamber - 6, made in the form of a rectangular container, the corners of which are equipped with special inserts, as a result of which the inside of the chamber takes the shape of a cylinder, and the rear upper wall is equipped with a reflector.

The main element of the developed electroflotator is electrolysis base-12, connected to the solar cell with a special plug device, and containing a special mechanism made of non-conducting material, mounted on the cathode, which allows simply adjusting the size of the interelectrode gap.

During the cleaning process, wastewater enters to the flotation chamber - 6 through a pipe with a valve 4, a pocket 5 and a slot 7.

When electrical voltage is applied to the electrodes of the electrolysis base, occurs the electrolysis of waste water, intensively generating negatively charged microdispersed electrolytic hydrogen bubbles, which, floating to the free surface of the wastewater, encounter in their path a microparticle of waste, the size of which is much larger than the size of microdispersed hydrogen bubbles.

Negatively charged microdispersed electrolytic hydrogen bubbles, having encountered a microparticle of waste, induce a positive charge on the outer surface of the microparticle of waste and, due to the resulting electrostatic force of attraction of opposite charges and surface tension forces, acting in the same direction, are fixed on the surface of the microparticle, forming a stable foam from hydrogen bubbles and microparticles waste, the lifting volume of which increases sharply and foam from hydrogen bubbles and microparticles of waste, due to the action of the increased Archimedes force, accelerates upward to the free surface of the wastewater.

The clean water free from waste, having passed through the post-treatment chamber - 8, is drained from the electroflotator through a pocket and a drain pipe with a tap - 10.

Pop-up foam from hydrogen bubbles and microparticles of waste is collected in the upper part of the flotation chamber and removed by a paddle device - 9 into a special receiving capsule.

After completing the washing of the electroflotator and removing all remaining water, a pipe with a tap is provided - 11.

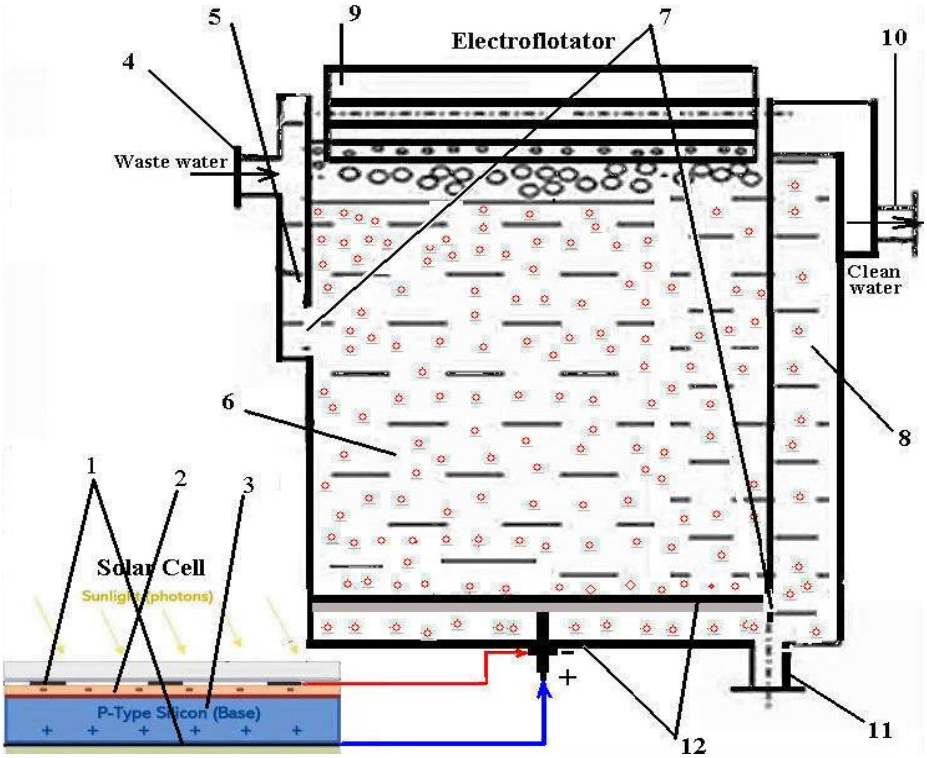


Figure 5. Design of the developed electroflotator continuous type, powered by a solar cell.

If the electrodes of the solar cell are connected to an electrical circuit, the load of which will be a developed concentrator-electroflotator for concentrating high quality fast-productive microalgae ***Chlorella*** [12], then in the process of flowing direct electric current through “green” sea or fresh water between the electrodes, the process of "green" water electrolysis in a concentrator - electroflotator is generated, which plays a major role in the concentration of high quality fast-productive microalgae ***Chlorella*** (Figure 4).

Figure 6 shows a general diagram of the developed electroflotator-concentrator, powered by a solar cell.

A structurally designed concentrator-electroflotator for concentrating high-calorie, rapidly multiplying ***Chlorella*** cells from “green” sea or fresh water, powered by direct electric current from a

solar battery through electrode-1, connecting a negative electrode of N-type silicon semiconductor layer -2 with the cathode terminal of the electroflotator-concentrator, located on a special plug device, connecting the external terminals with the electrodes of the electroflotator-concentrator and the positive electrode of the P-type silicon semiconductor layer -3, has a flotation chamber - 6, made in the shape of a rectangular container, the corners of which are equipped with special inserts,

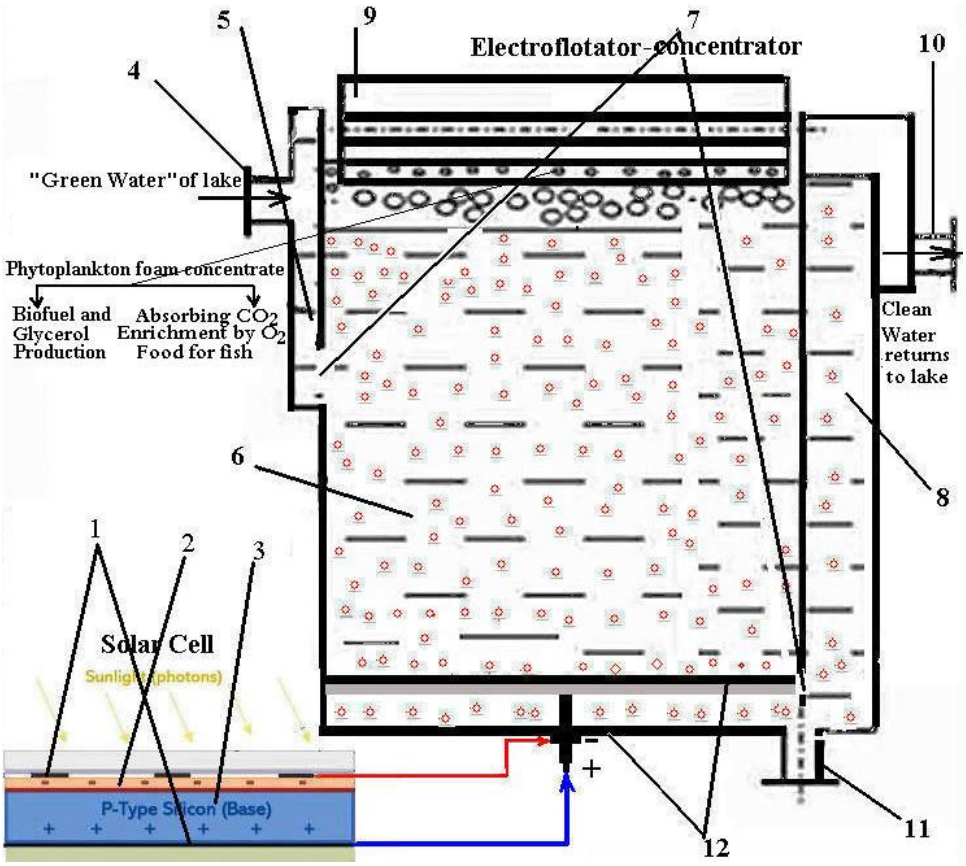


Figure 6. The general scheme of a specially designed electroflotator- concentrator, powered by a solar cell.

As a result, the inside of the chamber takes the shape of a cylinder, and the rear upper wall is equipped with a reflector.

The main element of the electroflotator being developed is the electrolysis base-12, connected to the solar cell by a special plug device and containing a special mechanism, made from non-conducting material, installed on the cathode, which allows simply adjusting the interelectrode gap.

During the concentration process, high-calorie, rapidly multiplying chlorella cells - “green” water enters to the flotation chamber - 6 through a pipe with valve 4, pocket 5 and slot 7.

When electrical voltage is applied to the electrodes of the electrolysis base, occurs the electrolysis of “green” water, intensively generating negatively charged microdispersed electrolytic hydrogen bubbles, which, floating to the free surface of “green” water, meet on their way high-calorie, rapidly multiplying chlorella cells, the size of which significantly exceeds the size of microdispersed hydrogen bubbles.

Negatively charged microdispersed electrolytic hydrogen bubbles, encountering high-calorie, rapidly multiplying ***Chlorella*** cells, attach to the cells due to the resulting action of the electrostatic force of attraction of different charges: negatively charged microdispersed electrolytic hydrogen bubbles and

the positively charged outer layer phospholipid bilayer of the membrane cell, as well as due to the force of surface tension, acting in one direction, forming a stable foam of concentrate from hydrogen bubbles and cells, the lifting volume of which increases sharply, and the foam from hydrogen bubbles and cells under the influence of the increased Archimedes force accelerates upward to free surface of "green" water.

Clean water, having passed through the post-treatment chamber - 8, is discharged from the electroflotator-concentrator through a pocket and a drain pipe with a tap - 10 into the lake. Floating foam from microdispersed hydrogen bubbles and ***Chlorella*** cells is collected in the upper part of the flotation chamber and removed by a paddle device - 9 into a special receiving capsule, from where the main part of the ***Chlorella*** foam concentrate is used to produce biofuel and glycerin, and the rest is returned to the lake, where the ***Chlorella*** foam concentrate cells multiply intensively due to the energy, released inside the ***Chlorella*** cells, obtained in the electroflotator-concentrator due to phosphorylation and the action of the formed during process of saturation of "green" water by hydrogen bubbles negatively charged solution of catholyte [12] surrounding them, which promotes its photosynthesis, i.e. absorbing carbon dioxide and enriching the environment with oxygen, and using it as food for breeding fish in the lake.

After completing the washing of the electroflotator-concentrator and removing all remaining water, a pipe with a tap is provided - 11.

The molecular model of the mechanism of generating photosynthesis in the ***Chlorella*** cell using solar energy is as follows.

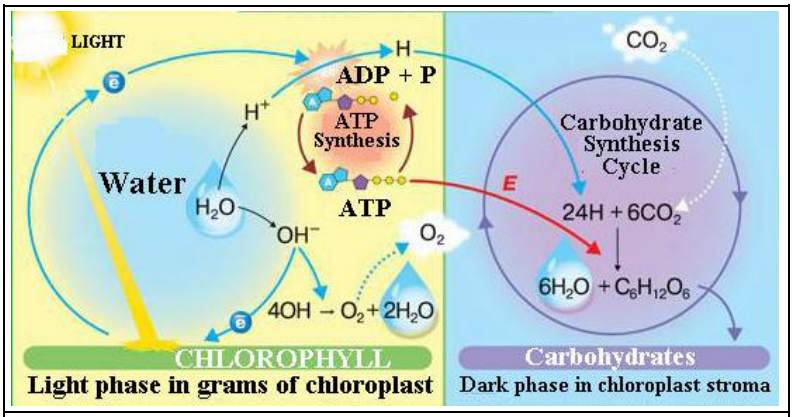
Photosynthesis is the process of formation organic compounds from CO_2 and oxygen O_2 from water, using light energy, passing through the chloroplasts and green pigments of the ***Chlorella*** cell.

Chloroplasts and folds of the cytoplasmic membrane of the ***Chlorella*** cell, contain a green pigment - chlorophyll, the molecules of which can be excited under the influence of sunlight, give up their electrons like the N-type silicon semiconductor layer.

These electrons are captured by electron carriers (NADP+ P - nicotine mid diphosphate).

In this case, the released energy of electron transfer is spent on heating the surrounding space, partly on the formation and reserve of ATP.

The process of photosynthesis is divided into a state caused by light and a state caused by light, associated with phase fixation: light and dark phases (Figure 7).



$$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$$

Figure 7. Photosynthesis.

During the light phase:

1. Water in the cell dissociates into the hydrogen cation $\boldsymbol{H^+}$ and the hydroxyl anion $\boldsymbol{OH^-}$:

   $H_2O \leftrightarrow H^+ + OH^-$ (1)

2. Under the influence of sunlight, chlorophyll molecules are excited, giving up their electrons, thereby becoming vacancy positive.
   Four hydroxyl anions of dissociated water, being attracted to the chlorophyll molecules that have become positive, give up four electrons, forming two water molecules and an oxygen molecule in the form of an oxygen bubble, which the ***Chlorella*** cell releases outward:

   $4OH^- - 4e \rightarrow 2H_2O + O_2\uparrow$ (2)

3. Under the influence of sunlight, chlorophyll molecules, when excited, give up their electrons, which neutralize the hydrogen cations $\boldsymbol{H^+}$ of dissociated water into neutral hydrogen atoms $\boldsymbol{H}$:

   $H^+ + e \rightarrow H$ (3)

These electrons are captured by electron carriers (NADP+ P - nicotine mid diphosphate) and the released energy of electron transfer is spent on heating of the surrounding space, partly on the formation and reserve of ATP.

During the dark phase:

The ***24*** hydrogen atoms ***H,*** neutralized in the light phase, in the Free State become unstable and in the dark phase react with ***6*** molecules of carbon dioxide $\boldsymbol{CO_2}$, assimilated by the cell.

To the result of the reaction are added ***6*** molecules of water $\boldsymbol{6H_2O}$, obtained in the light phase as a result of the attraction to the chlorophyll molecules, which have become positive, of four hydroxyl anions $\boldsymbol{4OH^-}$ dissociated water, which give up four electrons, forming two water molecules and an oxygen molecule in the form of an oxygen bubble, as a result, in the stroma (the space between the grana) of chloroplasts, using the energy of ATP and NADP • H, glucose $\boldsymbol{C_6H_{12}O_6}$ is formed in the dark phase.

Thus the equation for photosynthesis will be:

$6CO2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2\uparrow$ (4)

The molecular model of the mechanism of generating of the water electrolysis process, using a photoelectrolyzer, powered by solar energy, for the developed production of oxygen and hydrogen gases, is as follows.

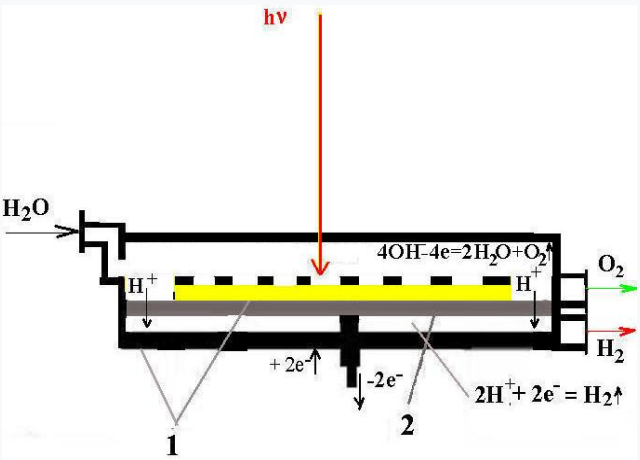


Figure 8. The developed photoelectrolyzer, which generates hydrogen and oxygen gases

The developed photoelectrolyzer [13] includes a layer of n-type silicon semiconductor with attached mesh anode and a cathode, interconnected by an electrical circuit for the flow of direct electric current generated under the influence of light on a layer of n-type silicon semiconductor with attached mesh anode, immersed in a conventional water (Figure 8).

The developed photoelectrolyzer has an inlet for water continuously supplied from the water tank to the photoelectrolyzer, and two separate outlet tubes for the discharge of oxygen gas bubbles and hydrogen gas bubbles.

The main element of the developed photoelectrolyzer is the electrolysis base (1), the connection to which is made in the form of a plug, equipped with a special mechanism, made from non-conductive material, which makes it possible to easily adjust the interelectrode gap.

Above the burned graphite cathode is a layer of n-type silicon semiconductor with an attached mesh anode, generating electrolytic oxygen bubbles, resulting from the impact of two photons of light on the n-type silicon semiconductor layer

The cathode is installed at the bottom of the photoelectrolyzer.

Between the layer of n-type silicon semiconductor with an attached mesh anode and the cathode there is a membrane made from fire hose material (2), which prevents the penetration of the resulting oxygen bubbles and four $\boldsymbol{OH^-}$ anions, formed as a result of the electrolysis process, into the cathode area and ensures the penetration of hydrogen cations to the cathode, which promotes intensive formation of microdispersed electrolytic hydrogen bubbles.

The photoelectrolyzer is continuously supplied with ordinary water.

In the n-type silicon layer, as a result of exposure by light, two photons “knock out” two electrons from the n-type silicon semiconductor layer, creating two vacant “holes” in it, “attracting” four electrons from the four hydroxyl anions $\boldsymbol{OH^-}$ of neighboring dissociated water molecule.

As a result, two water molecules are formed and an oxygen molecule is deposited on the mesh anode in the form of an oxygen bubble, like equation (2):

$$4OH^- - 4e \rightarrow 2H_2O + O_2\uparrow$$

Forming a gaseous oxygen molecule, which in water takes the form of an electrolytic bubble of oxygen gas, floats up from the anode as a bubble of oxygen gas and is removed from photoelectrolyzer through a separate oxygen outlet.

The "knocked out" electrons pass through a layer of n-type silicon with attached mesh anode to along an electrical circuit to the cathode, making it a negative pole, and the mesh anode, giving up electrons, becomes a positive pole.

Two positively charged hydrogen cations $\boldsymbol{2H^+}$ of dissociated water, due to the resulting negative charge of the cathode (the process of water electrolysis), are directed towards it and, having reached it, take two electrons from it, neutralizing of two separate hydrogen atoms, which, being in a Free State, combine with each other, forming a gaseous hydrogen molecule, which in water takes the form of an electrolytic bubble of hydrogen gas, which floats up from the cathode as a bubble of hydrogen gas and is removed from photoelectrolyzer through a separate hydrogen outlet:

$$2H^+ + 2e \rightarrow H + H \rightarrow H_2\uparrow \quad (5)$$

The resulting gas bubbles of oxygen and hydrogen, removed from photoelectrolysis through a separate oxygen pipeline goes into the oxygen cathode of the electric vehicle fuel cell and through a

separate hydrogen pipeline goes into the hydrogen anode of the electric vehicle fuel cell, were successfully used by the author for the non-stop movement of an electric vehicle on a constantly charged fuel cell that does not require recharging (Figure 9).

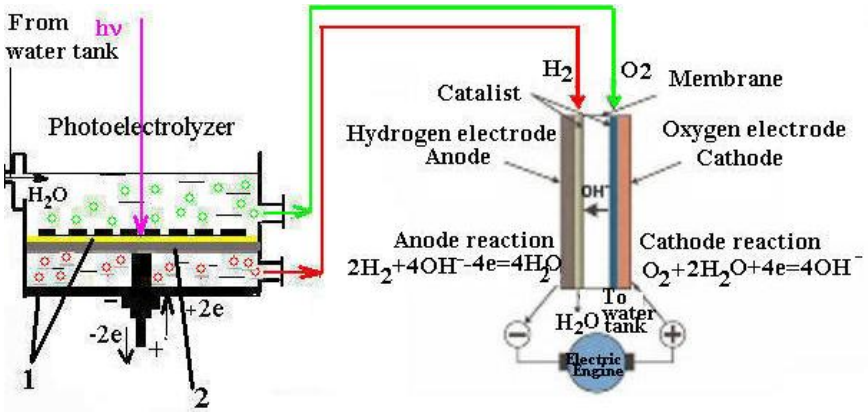


Figure 9. Full cycle of oxygen and hydrogen formation in the photoelectrolyzer by photoelectrolysis of ordinary water continuously coming from the tank; continuous charging of the fuel cell with the generated oxygen and hydrogen and the return of the released water vapor to the tank with ordinary water.

In an electric vehicle fuel cell, the anode and cathode are separated by a membrane.

Each electrode is coated with a layer of catalyst. As a result, at the oxygen cathode, due to the reaction of an oxygen molecule O_2 with two water molecules $2H_2O$, in which four electrons are taken that creates a positive potential at one contact of the electric engine (at the oxygen cathode), and four OH^- anions are formed, which subsequently react with two hydrogen molecules $2H_2$, formed in the hydrogen anode, while losing four electrons that create a negative potential on another of the electric engine contacts (on the hydrogen anode), form four water molecules (water vapor) $4H_2O$, which return to the tank with ordinary water, completing the full cycle: a tank with ordinary water + photoelectrolyzer: formation of hydrogen and oxygen gases + charging of fuel cells and operation of an electric vehicle engine on hydrogen and oxygen + water (water vapor) + tank for ordinary water.

$$O_2 + 2H_2O + 4e \rightarrow 4OH^- \rightarrow 2H_2 + 4OH^- - 4e \rightarrow 4H_2O \quad (6)$$

As a result, the electric vehicle will drive non-stop, using a constantly charged fuel cell that does not require recharging.

Thus, the presented molecular model of the generation of mechanism of the water electrolysis process, using a solar cell of a solar panel, powered by solar energy, allowed the author to: develop a new method and design a special electroflotator, which made it possible to quickly and economically (without the cost of electricity) complete purification of industrial wastewater and use purified water in the future; develop a new method and construct a special electroflotator - concentrator, which made it possible to quickly and economically (without the cost of electricity) obtain a concentrate of high-calorie, fast-reproducing ***Chlorella*** cells, the main part of which is used for the production of biofuel and glycerin, and the rest is returned to the lake, where the cells of the ***Chlorella*** concentrate are intensively multiply due to phosphorylation and the action of the negatively charged catholyte solution surrounding them, formed during the saturation of "green" water with hydrogen bubbles, which promotes their photosynthesis, i.e. absorbing carbon dioxide and enriching the environment with oxygen, and using it as food for the reproduction of fish in the lake.

The author also presents a molecular model of photosynthesis that promotes the absorption of carbon dioxide and enriches the environment with oxygen.

The presented molecular model of the generation mechanism of the water electrolysis process using a photoelectrolyzer, powered by solar energy, to produce gas oxygen and hydrogen allowed the author to: develop a new method and construct a special photoelectrolyzer, which made it possible to quickly and economically (without the cost of electricity) obtain oxygen and hydrogen gases.

The oxygen and hydrogen gases, obtained by the developed method and the constructed photoelectrolyzer, were successfully used to continuously charge the fuel cell of an electric vehicle, which allows the electric vehicle to move non-stop on a constantly charged fuel cell that does not require electrical charging.

RESULTS

The developed method and constructed electroflotator, powered by the solar cells of a solar panel, which generate electrolysis industrial wastewater, treats industrial galvanic wastewater, using the wastewater electrolysis process (Figure 5), in which toxic metals (*Zn*) of the wastewater are collected in the receiving header of the electroflotator, and the purified water is suitable for reuse in the galvanic process or for use in various other technologies without harming the flora and fauna of the environment were tested at the galvanic plant of *Packer YadPaz Tubes and Profiles Ltd* (*Kiryat Malachi, Israel*).

In a specially designed electroflotator, the zinc compounds in wastewater of galvanic production are dissociated into ions:

$$ZnCl_2 = Zn^{+2} + 2\,Cl^{-1} \quad (7)$$

In the galvanic wastewater treatment process, when a direct current is passed through the wastewater, containing a metal compound ($ZnCl_2$), one hydrogen cation ion H^+ and a zinc cation Zn^{+2} are brought closer to the cathode during the electrolysis process; hydrogen cation takes away one electron from it, and the zinc cation takes away two electrons.

The anode is approached by four *OH*- anions, which return four electrons, and two chlorine anions, Cl^{-1}, which return two electrons.

As a result, the neutral hydrogen atom *H*, formed at the cathode, becomes unstable in a Free State and, combining with another neighboring hydrogen atom *H*, forms a diatomic hydrogen molecule H_2, which floats to the free surface of the wastewater in the form of a hydrogen bubble, and the zinc cation Zn^{+2} turns into zinc atom *Zn*.

At the anode, the resulting neutral oxygen atom *O* in the Free State becomes unstable and, combining with another neighboring *O* atom, forms a diatomic oxygen molecule O_2, which floats to the free surface of the wastewater in the form of an oxygen bubble.

In addition, two water molecules are formed at the anode.

The neutral chlorine atom *Cl*, formed at the anode, combines with another neighboring *Cl* atom, forming a diatomic chlorine molecule Cl_2, which floats to the free surface of the wastewater in the form of a chlorine bubble.

As a result, hydrogen bubbles float to the surface of the cathode and a neutral zinc atom precipitates:

$$H^+ + e = H; \quad H + H = H_2\uparrow$$

$$Zn^{+2} + 2e = Zn \quad (8)$$

On the anode will be detached two molecules of water, the bubbles of hydrogen and chlorine:

$$2Cl^{-1} - 2e = Cl + Cl = Cl_2\uparrow$$

$$4OH^- - 4e = 2H_2O + O_2\uparrow \quad (9)$$

Table 1 presents the results of wastewater treatment of galvanic production, obtained after the completion of the general galvanic process at the plant of *Packer YadPaz Pipes and Profiles Ltd*.

Table 1. Results of the purification of waste water of galvanic plant by the developed electroflotator, powered by the solar cell of a solar panel.

	Zn^{2+}, mg/l	***Cl^{-}, mg/l***	***MAC, mg/l***
Before cleaning	8	250	100
After cleaning	0	25	0.5

Here ***MAC***: The maximum allowable concentration - the maximum concentration of chemical elements and their compounds in the environment, at which daily exposure to the human body does not cause pathological changes or diseases for a long time, determined by known research methods for any periods of life of the current and subsequent generations of people.

Table 3 shows that after cleaning, the *MAC* decreases from *100 mg/l* to *0.5 mg/l*, zinc content (Zn^{2+}) decreases from *8 mg/l* to *0*, the content of chlorine (Cl^{-}) decreased from *250mg/l* to *25 mg/l (90%).*

All zinc floated to the surface of the water and was taken by the receiving collector.

Chlorine gas, formed during the electrolysis of wastewater of galvanic production, floats to the surface of the wastewater in the form of a chlorine bubble and evaporates.

The obtained results confirm the high efficiency of the developed method and the designed electroflotator, powered by a solar cell of a solar panel, for treating wastewater from galvanic production.

The obtained zinc and the purified water can be reused in the galvanic process.

Purified water after the purification process complies with ***MAC*** standards and can be used for any technological process.

The developed method and the constructed electroflotator, powered by the solar cell of a solar panel, are easy to operate, allowing quickly and economically purification of wastewater of galvanic production without the cost of electricity.

Since the electroflotator being developed is a continuous type electroflotator, its use in series connection with other electroflotators makes it possible to improve the quality of wastewater treatment from galvanic production, a multiple of the number of electroflotators; parallel connection of electroflotators increases the amount of purified water, a multiple of the number of electroflotators.

The developed method and the constructed electroflotator-concentrator, powered by a solar cells of a solar panel, which generate “green” water electrolysis, make a high-quality concentrate of rapidly multiplying ***Chlorella*** cells from the “green” water of the lake.

Industrial tests of the developed method and the constructed electroflotator-concentrator (Figure 6) of the concentration of *Chlorella* cells from the “green” water of the lake conducted in the company *Israel Oceanographic & Limnological Research ltd*, using several different strains of *Chlorella* of the Red Sea (Eilat), showed the full concentration of rapidly multiplying *Chlorella* cells from the “green water” of the lake, leaving it transparently clean, which can be used in a closed ecological cycle: "green" lake water + electroflotator-concentrator + clean water + lake; electroflotator-concentrator + part of a high-quality concentrate of rapidly multiplying *Chlorella* cells + lake + photosynthesis: absorption of carbon dioxide and enrichment of the surrounding atmosphere with oxygen.

Using the direct electric *100V* voltage of the solar panel's solar cells for the lake's "green water" electrolyze during *5 seconds*, permits to reach a full concentration of rapidly multiplying *Chlorella* cells from the lake's “green” water, leaving it crystal clear.

Microbiologists of the *Israeli company Oceanographic & Limnological Research Ltd* stated that the cells of *Chlorella* foam concentrate remain alive and multiply intensively; the increase in *Chlorella* cells was no less than *100 times*.

Tests have shown that the concentration of *Chlorella* from the lake's "green water" can not only restore fresh water to the lake, but the bulk of this concentrate can be effectively used for high-quality biofuel and glycerin production, and the remainder, returned to the lake for intensive *Chlorella* cell reproduction in the clear water of the lake, which promotes their photosynthesis, i.e. absorbing carbon dioxide, enriching the environment with oxygen and using them as food for breeding fish in the lake.

The developed photoelectrolyzer, continuously supplied with ordinary water and powered by solar energy, generates electrolysis of ordinary water, leading to the production of separately pure gases of hydrogen and oxygen.

The production of pure hydrogen and oxygen gases by photoelectrolysis of ordinary water on a specially designed photoelectrolyzer showed the advantage of the developed photoelectrolyzer over other existing photoelectrochemical cells by the presence of a specially designed electrolysis base, including a membrane, made from fire hose material, located between a silicon semiconductor with an attached mesh anode and a burnt graphite cathode and a mechanism for regulating of the gap between the electrodes in the lower part of the photoelectrolyzer.

The operating parameters of the photoelectrolyzer to produce *1 m^3* of pure hydrogen and oxygen were: silicon semiconductor with an attached mesh anode with a cross-sectional area of *1 m^2*; the voltage of solar energy consumed at the electrodes is *100 V*; the constant electric current of solar energy consumed is *4 A*.

The developed photoelectrolyzer uses only *400 W* of solar energy to produce *1 m^3* of pure hydrogen and oxygen.

The energy efficiency of producing *1 m^3* of pure hydrogen and oxygen as a percentage will then be (*400 W*/*1300 W*) x *100 = 30.77%*, that is, quite high.

Tests have shown that the continuous generation of hydrogen and oxygen by a photoelectrolyzer of ordinary water in a specially designed photoelectrolyzer allows the fuel cell to be constantly charged and maintained in a charged state, which leads to non-stop movement of the electric vehicle without requiring recharging of the fuel cell under operating conditions.

CONCLUSION

The developed molecular mechanism for generating electrolysis of industrial wastewater, using solar cells of a solar panel made it possible to develop a method and a specially designed electroflotator, powered by solar cells of a solar panel, which purified industrial wastewater simply, quickly and economically without the cost of electricity.

Since the developed electroflotator is a continuous type electroflotator, its use in series connection with other electroflotators, makes it possible to improve the quality of industrial wastewater treatment, a multiple of the number of electroflotators; parallel connection of electroflotators increases the amount of purified water, a multiple of the number of electroflotators.

The developed molecular mechanism for generating electrolysis of “green” lake water, using solar cells of a solar panel made it possible to develop a method and construct an electroflotator-concentrator,

powered by solar cells of a solar panel, generating electrolysis of “green” water and allowing high-quality concentrate to be obtained from “green” lake water quickly multiplying *Chlorella* cells.

Tests have shown that the concentration of *Chlorella* cells from the lake's "green water" can not only restore fresh water to the lake, but the bulk of this concentrate can be effectively used to produce high-quality biofuels and glycerin, with the remainder returned to the lake for intensive proliferation of *Chlorella* cells in clear water of the lake, which promotes their photosynthesis, i.e. absorbing carbon dioxide, enriching the environment with oxygen and using them as food for breeding fish in the lake.

The author also presented a molecular model of photosynthesis that explains the absorption of carbon dioxide and the enrichment of the environment with oxygen.

The developed molecular model of the generation mechanism of the water electrolysis process, using a photoelectrolyzer, powered by solar energy, to produce gaseous oxygen and hydrogen allowed the author to develop a new method and design a special photoelectrolyzer, which made it possible to quickly and economically (without the cost of electricity) produce oxygen and hydrogen gases.

The oxygen and hydrogen gases, obtained by the developed method and the constructed photoelectrolyzer were successfully used to continuously charge the fuel cell of an electric vehicle, which allows the electric vehicle to move non-stop on a constantly charged fuel cell that does not require electrical charging.

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