UDC 663.63.0
Doi: 10.31772/2587-6066-2019-20-1-119-125

For citation: Pshenko E. B., Shestakov I. Ya., Shestakov V. I. [Features of electroactivated water production at a coaxial electrode location]. *Siberian Journal of Science and Technology.* 2019, Vol. 20, No. 1, P. 119–125. Doi: 10.31772/2587-6066-2019-20-1-119-125

Для цитирования: Пшенко Е. Б., Шестаков И. Я., Шестаков В. И. Особенности получения электроактивированной воды при коаксиальном расположении электродов // Сибирский журнал науки и технологий. 2019. Т. 20, № 1. С. 119–125. Doi: 10.31772/2587-6066-2019-20-1-119-125

FEATURES OF ELECTROACTIVATED WATER PRODUCTION AT A COAXIAL ELECTRODE LOCATION

E. B. Pshenko*, I. Ya. Shestakov, V. I. Shestakov

Reshetnev Siberian State University of Science and Technology
31, Krasnoyarsky Rabochy Av., Krasnoyarsk, 660037, Russian Federation
*E-mail: pshenko-64@mail.ru

Important characteristics of any product are quality and reliability. One of the factors affecting product reliability is the surface cleanliness provided by flushing with liquids. Electroactivated water and aqueous solutions can be used as liquids. On the basis of domestic and foreign experience, leading experts have developed methodological instructions for the widespread implementation of electro-activated water and aqueous solutions in instrument-making and mechanical engineering. For the production of electrochemically activated water and solutions, non-flowing and flow-through modular elements, as well as universal installations, have been developed. Analysis of the structures of these devices has shown that flat metal plates are used as electrodes, therefore there are volumes of water that are subjected to uneven electrical effects. As a result, the specific energy consumption for obtaining activated water is significant. The purpose of the work is to reduce the specific energy consumption in the production of activated water and aqueous solutions. Coaxial arrangement of the electrodes leads to reduction in energy consumption. The study of the electroactivator of water with a coaxial arrangement of electrodes allowed us to establish the optimal ratio between the volumes of anolyte and catholyte and the time of electrolysis of water and an aqueous solution of sodium chloride. A new indicator of efficiency (the specific energy consumption per unit of change in the pH of water or an aqueous solution) objectively reflects the perfection of the design of electroactivators. The research results can be used in instrument and mechanical engineering.

Keywords: water, electrochemical activator, anolyte, catholyte.

ОСОБЕННОСТИ ПОЛУЧЕНИЯ ЭЛЕКТРОАКТИВИРОВАННОЙ ВОДЫ ПРИ КОАКСИАЛЬНОМ РАСПОЛОЖЕНИИ ЭЛЕКТРОДОВ

Е. Б. Пшенко*, И. Я. Шестаков, В. И. Шестаков

Сибирский государственный университет науки и технологии имени академика М. Ф. Решетнева
Российская Федерация, 660037, Красноярск, просп. им. газ. «Красноярский рабочий», 31
*E-mail: pshenko-64@mail.ru

Важной характеристикой любого изделия является качество и надежность. Одним из факторов, влияющих на надежность изделий, является чистота поверхности, которая обеспечивается промывкой жидкостями. В качестве жидкости могут быть использованы электроактивированная вода и водные растворы. На основе отечественного и зарубежного опыта ведущими специалистами разработаны методические инструкции по широкому применению и использованию электроактивированных воды и водных растворов в приборо- и машиностроении. Для получения электрохимически активированной воды и растворов разработаны непроточные и проточные модульные элементы, а также универсальные установки. Анализ конструкций этих устройств показал, что в качестве электродов применяются плоские металлические пластины, поэтому имеются объемы воды, которые подвергаются неравномерному электрическому воздействию. В результате этого удельные энергозатраты на получение активированной воды значительны. Целью работы явилось снижение удельных энергозатрат при получении активированной воды и водных растворов. Коаксиальное расположение электродов приводит к снижению энергозатрат. Исследование электроактиватора воды с коаксиальным расположением электродов позволило установить оптимальное соотношение между объемами анолита и католита и временем электролиза воды и водного раствора хлорида натрия. Новый показатель эффективности (удельные энергозатраты на единицу изменения водородного показателя воды или водного раствора) *объективно отражает совершенство конструкции электроактиваторов. Результаты исследования могут быть использованы в приборо- и машиностроении.*

Ключевые слова: вода, электрохимический активатор, анолит, католит.

Introduction. The amazing properties of water obtained by electrolysis were discovered in different countries independently. The unusual properties of the electroactivated water were discovered by chance, not by the doctors, but by the gas workers, not in the laboratory, but on the drilling test towers of the Institute SredAzNIIGaz. This institute was located in Tashkent and was engaged in gas production in the Kyzyl Kum desert. The scientists of this institute came up with an original installation: on the basis of electrolysis, two solutions were obtained from ordinary water. One of them, catholyte, was used to produce drilling mud with high physical and chemical indices. Another solution – anolyte – was used for coagulation of excess clay phase.

The study and use of electroactivated water solutions began in 1978 in the organization "Sreda-3 NIIgaz", where S. A. Alekhin, V. M. Bakhir, N. A. Mariam-Polsky, U. D. Mamadzhanov et al. worked [1–3].

Three international symposiums were held on the electrochemical activation of water and aqueous solutions [4–6]. In the introductory report at the first symposium the President of the Academy of Medical and Technical Sciences of Russia, Doctor of Technical Sciences, Professor. B. I. Leonov noted that "electrochemical activation of water and water solutions is the technology of the future, which will allow creating an ecologically clean future for the Earth and other planets". Further work confirms the conclusion of the scientist [7–9].

The widespread use of activated water is presented in article [10]. Water with pH 2–3 was introduced into a solution of ferric chloride for etching printed circuit boards [11]. The etching rate has increased, the consumption of chemicals has decreased, the process of industrial waste regeneration has been simplified. For cleaning printed circuit boards, a composition consisting of electroactivated water (pH 12–14) and caustic soda has been developed [12]. The cleaning time is reduced several times. When cutting metals, the redox potential of the emulsion was measured at the time of chip removal. As soon as the cutting began, the redox potential became negative. Having added electroactivated water (catholyte) with redox potential from minus 300 to minus 800 mV to the emulsion, a new coolant-lubricant was obtained [13]. Working on the process of industrial waste utilization, the authors improved the previously developed coolant-lubricant. The activator was close to the metalworking machine. At the same time, the catholyte was directed to the cutting zone, and the anolyte was mixed with the spent emulsion. The effect of increasing the cutting tool durability was obtained, the emulsion stability increased 1.5 times, and the used coolant did not require additional treatment for utilization [14].

For washing printed circuit boards, various liquids are used. In the study [15] electroactivated water was used for this purpose, which led to a reduction in the consumption of chemicals.

To obtain electrochemically activated water and solutions such devices are used as: STEL installations, Aquachlor, Izumrud; flow modular elements PEM-3, PEM-7, PEM-9; universal MB-11, MB-26, etc. With a small consumption of activated water, a large variety of electroactivators are offered: Iva-1, Melesta, AP-1, Aqualife and others (fig. 1).

Analysis of the structures of these devices showed that flat metal plates are used as electrodes, therefore there are volumes of water that are exposed to uneven electrochemical effects. In addition, due to the small surface area of the electrodes, the current density increases, which, according to the Tafel equation, leads to an increased overvoltage of electrochemical processes. As a result of this, the specific energy consumption for obtaining activated water is significant and amounts to 15÷30 W · h / l. The calculation is made on the basis of passport data.

In the Espero-1 electroactivator shown in fig. 2, the anode is made in the form of a graphite rod of square section, the cathode is made of thin-sheet steel in the form of a cylindrical shell. The electrodes are mounted coaxially to each other. The anode is in the center, the cathode is in the periphery. As a result, all the water in the activator is subjected to electrochemical exposure, which leads to a significant reduction of energy consumption to 2÷3 W · h / l (when dissolving table salt in water 10 g/l). On the side surface of the anode, due to the right angle, the electric field strength and current density are increased, which adversely affects the efficiency of the electroactivator.

Methods and equipment of research. To study the activator with a coaxial arrangement of electrodes, a device with a graphite rod of circular cross-section was manufactured [16]. Fig. 3 shows an experimental electroactivator.

Tarpaulin cloth is used as the diaphragm. The anode is a graphite rod, the cathode is a hollow stainless steel cylinder. Fig. 4 shows the assembled electroactivator, power supply, multimeter and pH meter.

Methods of conducting experiments in the study of electroactivator with a coaxial arrangement of electrodes:

1. Filling the glass tank with cold tap water.
2. Settling water with the lid open for at least 8–10 hours at room temperature.
3. Control the pH of the source water.
4. Filling the anodic and cathodic spaces of the activator with water.
5. Installation of the electrode in the anode space.
6. Pause from 3 to 5 minutes to level the water levels in the cathode and anode spaces.
7. Electrochemical effect on water by passing a current.
8. Current control.
9. After disconnecting the voltage, the anolyte is discharged into a separate container.
10. Control of pH of the anolyte (pHA) and the catholyte (pHK).

Fig. 1. Electric water activators: Iva-1, Melesta, AP-1

Рис. 1. Электроактиваторы воды: Ива-1, Мелеста, АП-1

Fig. 2. Electroactivator “Espero-1”

Рис. 2. Электроактиватор «Эсперо-1»

Fig. 3. Experimental electroactivator

Рис. 3. Экспериментальный электроактиватор

Fig. 4. Used equipment

Рис. 4. Используемое оборудование

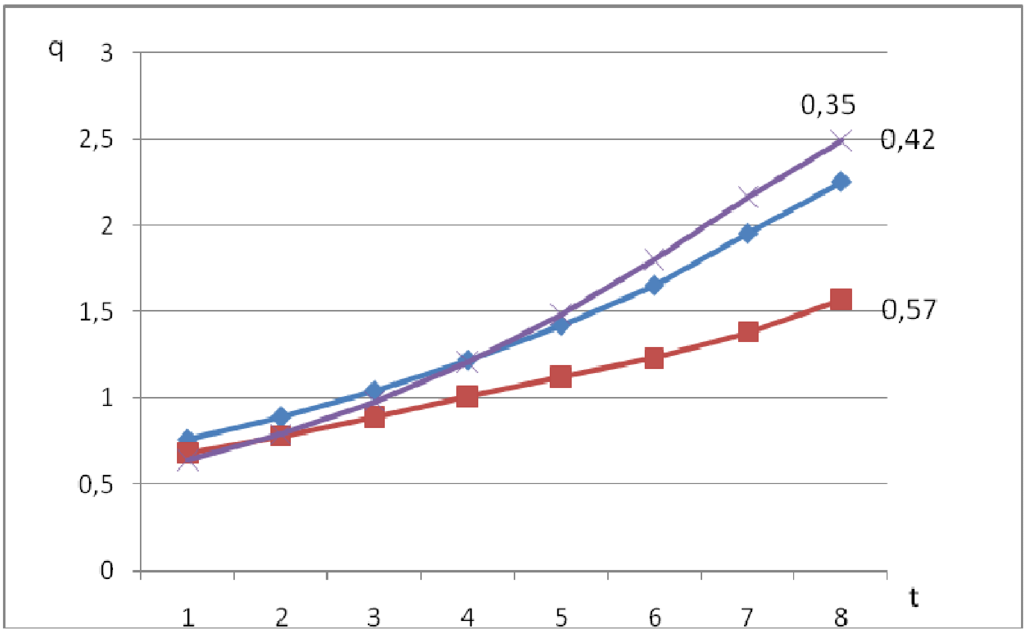

Fig. 5. The change in pH of anolyte and catholyte from the time of activation of tap water

Рис. 5. Изменение pH анолита и католита от времени активирования водопроводной воды

Specific energy consumption is determined by the formula:

$$Q = I \cdot U{\cdot}\tau/60{\cdot}V, \qquad (1)$$

where U is the voltage on the electrodes, V; V is the volume of activated water, l; I is the amperage, A; τ is the time of water activation, min.

We believe that the specific energy consumption does not reflect the efficiency of the electroactivator. It is proposed to evaluate the operation of the device according to the following indicator:

$$q = Q/\Delta pH, \qquad (2)$$

where q is the specific energy consumption per unit of change in the pH of water or an aqueous solution; ΔpH = pHK – pHA is the difference in pH values of catholyte and anolyte.

The experiments were conducted at a different ratio of the volumes of anolyte and catholyte from 0.35 to 1.72.

Results. Experiments have shown (fig. 5) that the minimum value of specific energy consumption per unit of pH change is typical for a volume ratio of 0.57, therefore, further experiments were carried out with this ratio. It can be seen from the figure that with electrolysis time from 3.5 to 7 minutes specific energy consumption for the specified ratio of volumes is 15–20 % less than for other values.

Fig. 6 shows the changes in the pH of anolyte and catholyte from the time of water activation. It follows from the graph that the maximum change in the hydrogen index (pH) occurs in 7 minutes of electrochemical activation of water.

For the experiments an aqueous solution of sodium chloride (0.9 % physiological solution widely used in medicine and in everyday life – the Espero activator) was used. The results are presented in fig. 7, 8.

The nature of the change in the pH of the solution and the specific energy consumption does not change with the activation time.

However, the specific energy consumption is an order of magnitude less and the maximum change in the pH value occurs in 3 minutes.

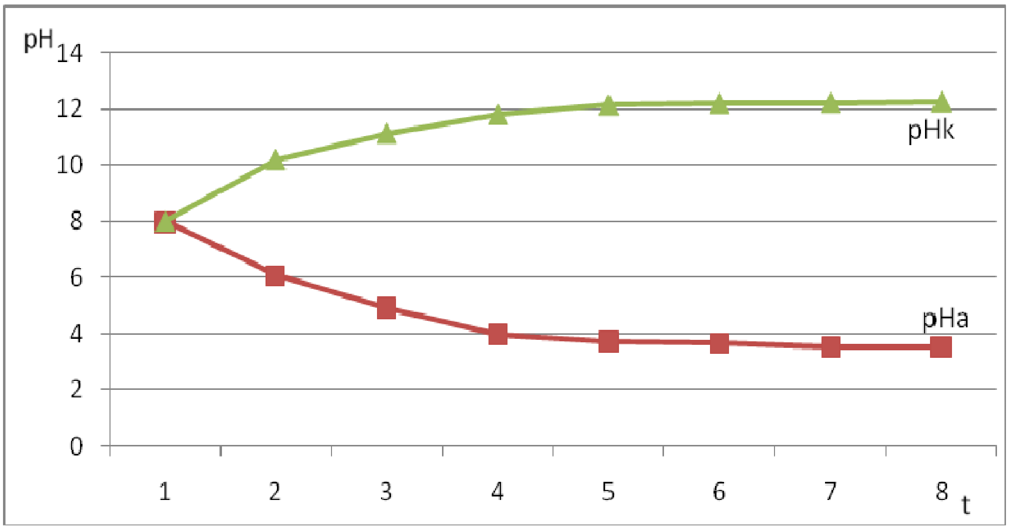

Fig. 6. The change in pH of anolyte and catholyte from the time of water activation

Рис. 6. Изменение pH анолита и католита от времени активации воды

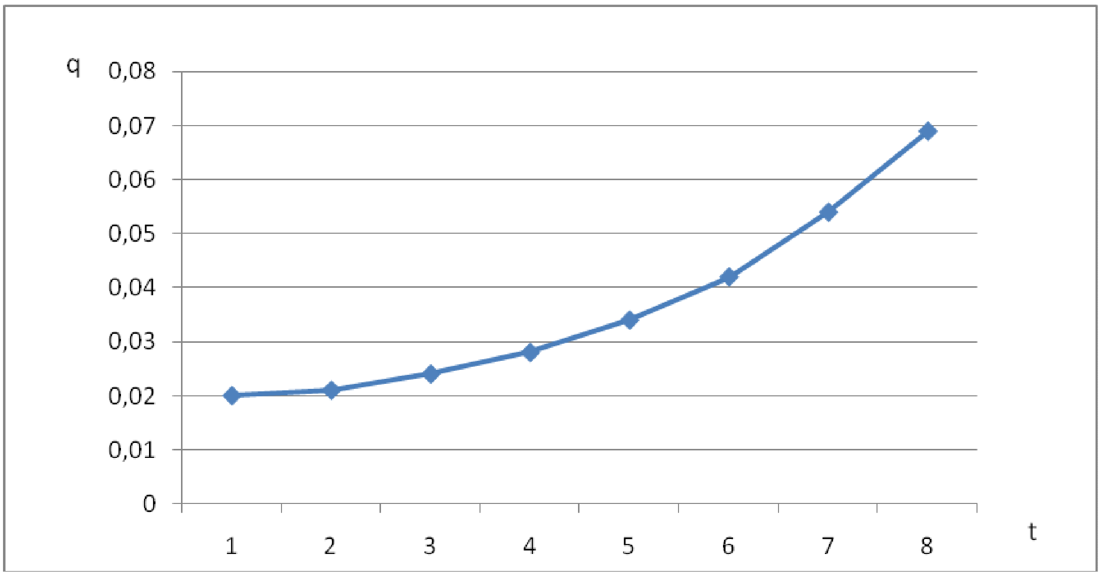

Fig. 7. Specific energy consumption per unit of change using an aqueous solution of sodium chloride (0.9 % physiological solution)

Рис. 7. Удельные энергозатраты на единицу изменения с использованием водного раствора хлорида натрия (0,9 % физиологический раствор)

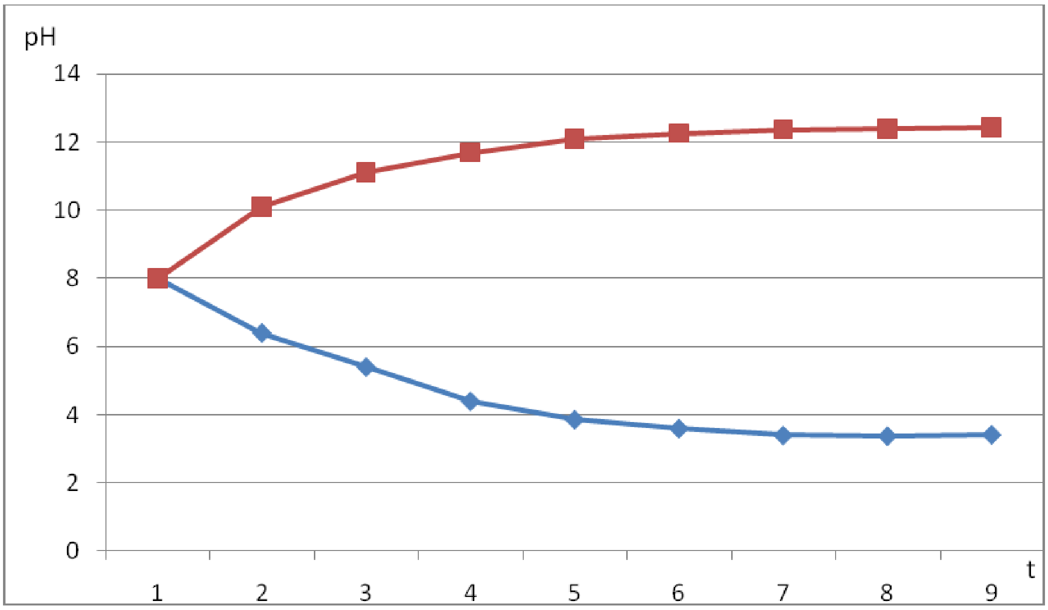

Fig. 8. The change in the pH of the anolyte and catholyte from the time of activation of water using an aqueous solution of sodium chloride (0.9 % physiological solution)

Рис. 8. Изменение pH анолита и католита от времени активации воды с использованием водного раствора хлорида натрия (0,9 % физиологический раствор)

Specific energy consumption per unit of change in the water pH

Model	Ratio V_A/V_k	Specific energy consumption q
Melesta	0.6	2.86
AP-1	0.33	2.77
IVA-1	0.75	2.96
Aqualife	0.11	2.76
Espero-1	0.2	1.5
Electroactivator under study	0.57	1.25

The results of the calculations of the specific energy consumption per unit of change in the water pH are shown in the table. It follows from the table that the electrical activator has the minimum value of specific energy consumption per unit of change in the pH value.

Conclusion. Existing devices for the electrochemical activation of water and aqueous solutions have design flaws, and therefore have increased specific energy consumption. The developed electroactivator with a coaxial arrangement of the electrodes has the lowest specific energy consumption per unit of change in the pH value, which is very important at the present time.

References

1. Bahir V. M., Liakumovich A. G., Kirpichnikov P. A., Spektor L. E., Mamadzhanov U. D. [The physical nature of the phenomena of activation of substances]. *Izv. AN UzSSR. Ser.tekhn. nauk.* 1983, No. 1, P. 60–64 (In Russ.).

2. Kirpichnikov P. A., Bakhir V. M., Gamer P. U., Dobrenkov G. A., Liakumovich A. G., Fridman B. S., Agadzhanyan S. I. [On the nature of electrochemical activation of media]. *Dokl. AN SSSR.* 1986, No. 286 (3), P. 663–666 (In Russ.).

3. Prilutsky V. I., Bakhir V. M. *Elektrokhimicheski aktivirovannaya voda: anomal'nye svoystva, mekhanizm biologicheskogo deystviya* [Electrochemically activated water: anomalous properties, mechanism of biological action]. Moscow, VNIIIMT, 1997, 228 p.

4. [Electrochemical activation in medicine, agriculture, industry]. *First International Symposium Coll. Report*. Moscow, Ekran Publ., 1997, 248 p. (In Russ.).

5. Alekhin S. A. [Electrochemical activation]. *Second International Symposium. Abstracts and short messages*. Part 1. Moscow, VNIIMT, MIS-RT Publ., 1999, 210 p. (In Russ.).

6. Bahir V. M. [Electrochemical activation]. *Third International Symposium. Abstracts and brief messages*. Moscow, VNIIMT Publ., 2001, 293 p. (In Russ.).

7. Shestakov V. I. [Electroactivator of water]. *Actual problems of aviation and cosmonautics: theses IX Vseros. scientific-practical conf. creative youth*. Krasnoyarsk, SibSAU Publ., 2013, Vol. 1, P. 504 (In Russ.).

8. Tachikawa H., Takada T. [Proton transfer rates in ionized water clusters (H 2 O) n (n = 2–4]. *RSC Advances*. 2015, Vol. 5, No. 9, P. 6945–6953.

9. Herr J. D., Talbot J., Steele R. P. [Structural progression in clusters of ionized water, (H2O) n = 1–5 +].

The Journal of Physical Chemistry A. 2015, Vol. 119, No. 4, P. 752–766.

10. Kozlov A. F. [From printed circuit boards to air purification]. *Second International Symposium. Electrochemical activation in medicine, agriculture, industry. Part 2.“MIS-RT”*. 1999, No. 21-1, P. 34–36 (In Russ.).

11. Afanasov V. M. *Etching solution for printed circuit boards* [Etching solution for printed circuit boards]. A.S. No. 1018266 USSR, No. 3324018, 2003.

12. Afanasov V. M. *Composition for cleaning printed circuit boards* [Composition for cleaning printed circuit boards]. A.S. No. 1018267 USSR, No. 3323368, 1983.

13. Kozlov A. F., Bolotsky E. N., Teveleva S. I. et al. *Lubricating fluid for mechanical processing of metals* [Lubricating fluid for mechanical processing of metals]. A.S. No. 1119340, 1982.

14. *A method of producing cutting fluid for cutting metals* [A method of producing cutting fluid for cutting metals]. A.S. No. 1336552, 1986.

15. Medvedev A. [Installation fluxes. Flush or not flush]. *Komponenty i tekhnologii*. 2001, No. 4, P. 96–98 (In Russ.).

16. Shestakov I. Ya., Shestakov V. I. *Elektroaktivator* [Electrical activator]. Patent RF, No. 147543, 2014.

Библиографические ссылки

1. Физическая природа явлений активации веществ / В. М. Бахир, А. Г. Лиакумович, П. А. Кирпичников [и др.] // Изв. АН УзССР. Сер. техн. науки. 1983. № 1. С. 60–64.

2. О природе электрохимической активации сред / П. А. Кирпичников, В. М. Бахир, П. У. Гамер [и др.] // Докл. АН СССР. 1986. № 286(3). С. 663–666.

3. Прилуцкий В. И., Бахир В. М. Электрохимически активированная вода: аномальные свойства, механизм биологического действия. М. : ВНИИИМТ, 1997. 228 с.

4. Электрохимическая активация в медицине, сельском хозяйстве, промышленности // I Междунар. симп. : сб. докл. М. : ВНИИМТ ; АО НПО “Экран”, 1997. 248 с.

5. Алёхин С. А. Электрохимическая активация // II Междунар. симп. : тез. докл. и краткие сообщения. М. : ВНИИМТ ; МИС-РТ, 1999. Ч. 1. 210 с.

6. Бахир В. М. Электрохимическая активация // III Междунар. симп. : тез. докл. и краткие сообщения. М. : ВНИИМТ, 2001. 293 с.

7. Шестаков В. И. Электроактиватор воды // Актуальные проблемы авиации и космонавтики : тез. IX Всеросс. науч.-практ. конф. творческой молодёжи / СибГАУ. Красноярск, 2013. Т. 1. 504 с.

8. Tachikawa H., Takada T. Proton transfer rates in ionized water clusters (H 2 O) n (n= 2–4) // RSC Advances. 2015. Vol. 5, No. 9, P. 6945–6953.

9. Herr J. D., Talbot J., Steele R. P. Structural progression in clusters of ionized water,(H2O) n = 1–5+ // The Journal of Physical Chemistry A. 2015. Vol. 119, No. 4. P. 752–766.

10. Козлов А. Ф. От печатных плат до очистки воздуха // Электрохимическая активация в медицине, сельском хозяйстве, промышленности : II Междунар. симп. Ч. 2: “МИС-РТ”. 1999. № 21-1. С. 34–36.

11. А. с. 1018266. Раствор для травления печатных плат / В. М. Афанасов. № 3324018/18-21 ; заявл. 20.07.81 ; опубл. 15.05.83, Бюл. 18.

12. А. с. 1018267. Состав для очистки печатных плат / В. М. Афанасов. № 3323368/18-21 ; заявл. 20.07.81 ; опубл. 15.05.83, Бюл.18.

13. А. с. 1119340. Смазочно-охлаждающая жидкость для механической обработки металлов / А. Ф. Козлов, Е. Н. Болотский, С. И. Тевелёва [и др.]. 1982.

14. А. с. 1336552. Способ получения смазочно-охлаждающей жидкости для резания металлов. 1986.

15. Медведев А. Монтажные флюсы. Смывать или не смывать // Компоненты и технологии. 2001, № 4. С. 96–98.

16. Патент на полезную модель. Электроактиватор / И. Я. Шестаков, В. И. Шестаков. № 147543 ; Опубл. 10.11.2014, Бюл. № 31.

Pshenko Elena Borisovna – Cand. Sc., Associate Professor at the Department of Mechanical Engineering Technology, Reshetnev Siberian State University of Science and Technology. E-mail: pshenko-64@mail.ru.

Shestakov Ivan Yakovlevich – Dr. Sc., associate professor, professor; Reshetnev Siberian State University of Science and Technology. E-mail: yakovlevish@mail.ru

Shestakov Vladislav Ivanovich – student, Reshetnev Siberian State University of Science and Technology.

Пшенко Елена Борисовна – кандидат технических наук, доцент кафедры технологии машиностроения; Сибирский государственный университет науки и технологий имени академика М. Ф. Решетнёва. E-mail: pshenko-64@mail.ru.

Шестаков Иван Яковлевич – доктор технических наук, доцент, профессор, Сибирский государственный университет науки и технологий имени академика М. Ф. Решетнёва. E-mail: yakovlevish@mail.ru

Шестаков Владислав Иванович – студент, Сибирский государственный университет науки и технологий имени академика М. Ф. Решетнёва.