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CRITERIA FOR THE SELECTING PARAMETERS ANODE POLARIZATION PROCESS OF SUBSTANCES ON THE ION-SELECTIVE ELECTRODES SURFACE

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The methods of making solid-phase ion-selective electrodes, as primary converters for controlling the concentration of harmful substances during environmental monitoring of natural and technological waters, have been analyzed. The algorithm of the method of creating an ion-selective electrode with a sulfide function (IESF) is developed. The results of processes of anodic polarization of an electrode-active substance on the surface of an ion-selective electrode are given. The dependences of the time of application of the electrode-active material Ag2S at a constant current density of 6, 10, 20, 30, 40 μA/mm^2 are obtained. The mathematical models of creation of the IESF with the help of one-parametric regression analysis are developed. *Key words:* ecological safety, ion-selective electrode, anodic polarization, regression analysis, model.

Критерії вибору параметрів процесу анодної поляризації речовин на поверхні іон-селективних електродів. Тичков В.В., Трембовецька Р.В., Гальченко В.Я. Проаналізовані методи виготовлення твердофазних іон-селективних електродів як первинних перетворювачів для контроля концентрації шкідливих речовин при екологічному моніторингу природної та технологічної води. Розроблений алгоритм методу виготовлення іон-селективного електроду з сульфідною функцією (ІСЕСФ). Наведено результати процесів анодної поляризації електродно-активної речовини на поверхню іон-селективного електроду. Отримані залежності часу нанесення електродно-активного матеріалу Ag2S при постійній щільності струму 6, 10, 20, 30, 40 мкА/мм^2. Розроблені математичні моделі створення ІСЕСФ за допомогою однопараметричного регресійного аналізу. *Ключові слова:* екологічна безпека, іон-селективний електрод, анодна поляризація, регресійний аналіз, модель.

Критерии выбора параметров процесса анодной поляризации веществ на поверхности ион-селективных электродов. Тычков В.В., Трембовецкая Р.В., Гальченко В.Я. Проанализированы методы изготовления твердофазных ион-селективных электродов как первичных преобразователей контроля концентрации вредных веществ при экологическом мониторинге природной и технологической воды. Разработанный алгоритм метода изготовления ион-селективного электрода с сульфидной функцией (ИСЕСФ). Приведены результаты процессов анодной поляризации электродно-активного вещества на поверхность ион-селективного электрода. Получены зависимости времени нанесения электродно-активного материала Ag2S при постоянной плотности тока 6, 10, 20, 30, 40 мкА/мм^2. Разработаны математические модели изготовления ИСЕСФ с помощью однопараметрического регрессионного анализа. *Ключевые слова:* экологическая безопасность, ион-селективный электрод, анодная поляризация, регрессионный анализ, модель.

Formulation of the problem. The water of rivers and seas is polluted by industrial discharges, sewage from urban sewers, livestock complexes, as well as toxic chemicals and mineral fertilizers washed off the fields. Almost 40% of wastewater is only partially purified or not cleaned at all. At the same time, the condition of many treatment plants is in such a state that most chemical compounds pass unhindered through them. For modern objects of automation of industrial production there are quite a variety of functional tasks that put forward stringent requirements to the level of automation, methods and means of ensuring the efficiency and reliability of measuring control systems. One of the systems elements are the primary information converters, whose task is to determine the composition and concentration of substances, pressure, temperature and other parameters in automatic control systems of industrial production, in chemical, ecological studies, in agriculture and in a number of other areas. Thus, the varieties of technological parameters require the development of reliable operating automatic control systems, where an operative measurement of physical and chemical quantities is required, based on different principles. Particular importance of measuring concentration is acquired for labor protection, solving the problem of environmental protection, in crisis, emergency and technogeny situations. Usually in such cases, fast and accurate measuring instruments are required as part of automated process control systems that ensure the measurement of parameters, while directly determining the composition and properties of process water.

The relevance of research. The most important technological parameter for automatic control systems (ACS) is the composition of processing materials; therefore measuring analytical control is an obligatory element of any ACS of process water, which is carried out directly in the production stream. The term technological water (or process water) means water, which is used to provide the technological process at all stages of production and operation of the enterprise, as a whole, and directly contacts raw materials and intermediate products in the technological process [1]: from selection, washing and use in the process itself and ending with aqueous solutions that form waste water. The quality of process water is determined by the complex of its chemical components and physical properties that determine the suitability of water for certain types of water use. The main factors that affect the quality of the technological process include, for example, water composition, pressure and temperature in process units and units.

The **purpose** of this work is to develop a model of primary information converters for flow injection ACS and to assess the effect of their application on the quality of process water control, depending on the proposed methods for manufacturing ion-selective electrodes based on anodic polarization.

Communication of author's development with important scientific and practical tasks. Research and innovation in the development of environmental monitoring techniques were performed according to the international study on the project Tempus NETCENG "The new model of the third cycle in the field of engineering education in connection with the Bologna process in the BY, RU, UA" at the Department Instrument Making, Mechatronics and Computerized Technologies of Cherkasy State Technological University [2].

Analysis of recent research and publications. Solid membrane ion-selective electrodes, as a rule, are made of homogeneous and heterogeneous materials [3-6]. As homogeneous materials, single crystals, solidified salt melts, pressed powdered salts or ceramic materials pressed into the pellets, which are obtained by sintering or pressing at high temperature, vanadium and tungsten bronze oxides, stoichiometric compounds with cationic disordering (such as halides and silver chalcogenides), non-stoichiometric compounds with a high intrinsic disorder (such as Al_2O_3), a compound with a high concentration of anionic vacancies, which realized due to disordering impurity (such as a stabilized Zr_2). Heterogeneous materials are powdered precipitates of sparingly soluble salts that are embedded in an inert matrix.

The main methods of manufacturing solid ion-selective electrodes are [3−6]:

– pressing under pressure − 2500 kg/cm^2 at a temperature of 1000−1100 °C for 20−30 hours; 1400-20000 atm. at a temperature of 150−200°C; 250−300 kg/cm^3; 120 kgf/cm^2 at a temperature of 120±5°C for 90 minutes; 120−130 kg/cm^2 under a vacuum of 10-2−10-3 mm.rt. st. at a temperature of 800-1000°C for 1.5−2 hours; 50.5 kg/mm^2; 10 atm/cm^2 at a temperature of 500°C; 7.5 t/cm^2 at 150 °C for several hours; 9000 kg/cm^2 for 3 minutes at an annealing of 25−180 °C; 20 t/cm^2 at room temperature for 24 hours; 3000−5000 kgf/cm^2 at 90−210°C for 5−15 minutes;

– anodic polarization − 0.75 A/dm^2; 400 Cl/dm^2; 0.2 A/dm^2 for 30 minutes and 0.3 A/dm^2 for 10 minutes; 0.21−0.25 V pulsed sinusoidal voltage in for 10−15 seconds;

– cathodic polarization − 0.5−0.6 A/dm^2; 300-360 Cl/dm^2; 0.25÷-0.21 V pulsed sinusoidal voltage for 50−60 seconds;

– vacuum deposition − deposition rate 0.5 nm/s at a temperature of 200−350°C; 4000 A/min at a temperature of 1700 °C for 2 hours and at a temperature of 2000°C for 5 minutes,

– mixing with organic material − polystyrene, epoxy and silicone compound, paraffin, polytetrafluoroethylene, graphite and polystyrene, fluoroplastic emulsion, rubber, polyvinyl chloride, graft polymer-based copolymer with acrylonitrile, BF glue.

Allocation of previously unresolved parts of the general problem to which this article is devoted. There remain a number of unresolved problems that play an important role in the development of automatic control systems (ACS). One of such tasks is to improve the quality of primary information converters, in particular for control of process water. The quality of process water is determined by the complex of its chemical components and physical properties that determine the suitability of water for certain types of water use; therefore it is very important to determine these parameters in real time. At the moment, automatic operational control of technological parameters in the ACS is performed with insufficient accuracy, and for some technological processes it is not realized at all.

To assess the effect of the use of ion-selective electrodes on the quality of process water control, the main task is to develop methods for manufacturing primary information converters for flow-injection systems for automatic control of process water [7−8].

The main criteria for limiting anodic polarization in the manufacture of an ion-selective electrode include the thickness of the electrode-active membrane, the resistance of the electrode, and the polarization time.

The thickness of the electrode-active material affects the overall resistance of the ion-selective electrode. The larger the thickness, the greater the resistance of the ion-selective electrode, which affects the characteristics of the ion-selective electrode itself, namely: the response time increases, which entails the need to increase the input resistance of the measuring device, which reaches several gigaOm.

Currently, these criteria are not sufficiently developed.

Novelty. The novelty of the study is the formulation of rational criteria for the anodic polarization of an electrode active substance on the surface of ion-selective electrodes.

Methodological or general scientific value. A unified methodology for the formation of an electrode active substance on the surface of ion-selective electrodes

Statement of the main material. The formation of an electrode-active element of an ion-selective electrode is carried out using the example of a sulfide-silver electrode according to the algorithm [9] (Fig. 1).

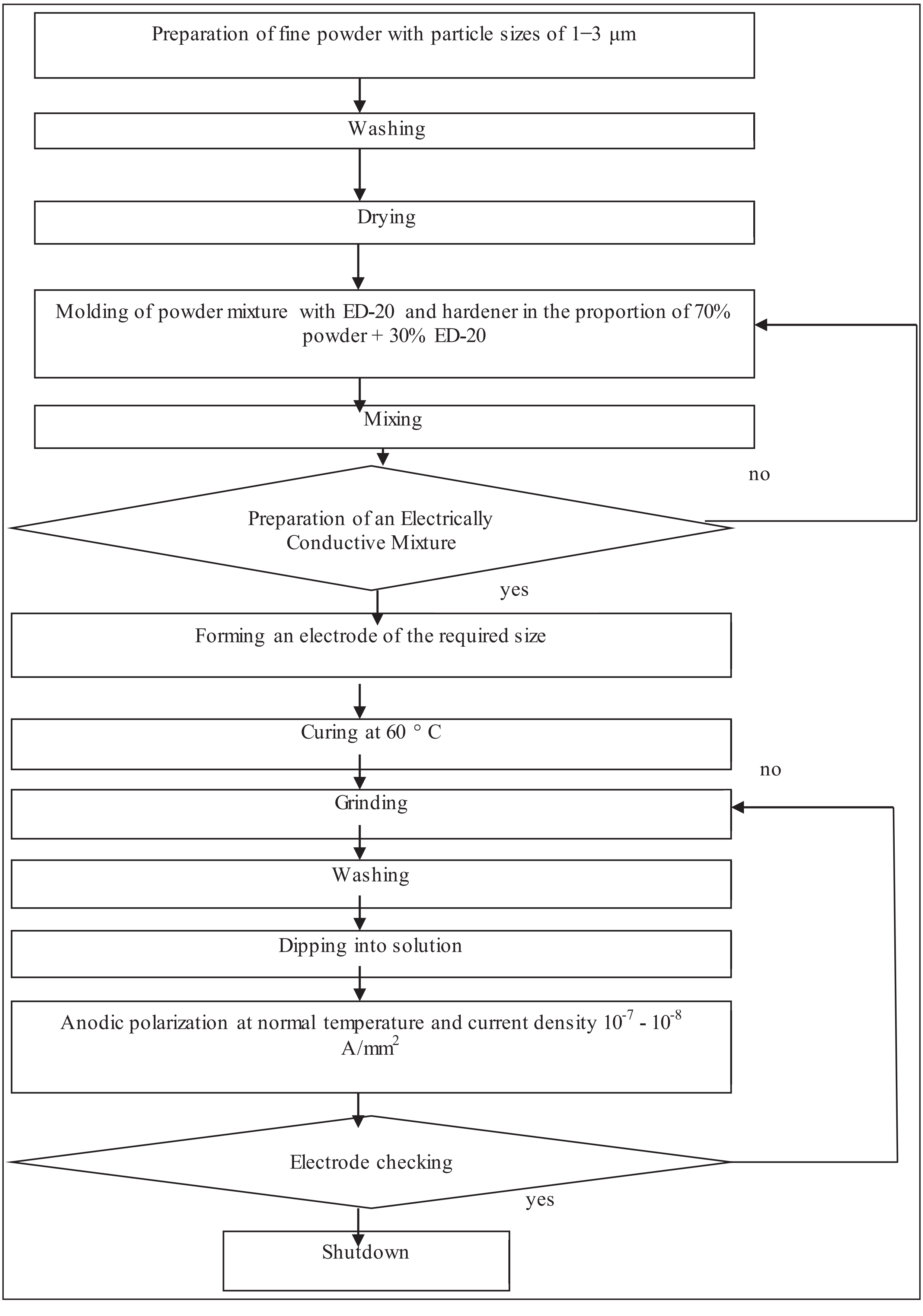


Fig. 1. Algorithm for forming an electrode-active element of an ion-selective electrode by the example of a sulfide-silver electrode

Calculation of the thickness of the Ag2S layer deposition on the silver substrate is carried out according to the Faraday law:

$$m = k \cdot q = k \cdot I \cdot t, \quad (1)$$

where m – the mass of the substance released on the electrode, kg;

k − the coefficient associated with the atomic mass of substance A, $k = \frac{1}{F}\frac{A}{n}$;

q – the electric charge, Cl;

I − the strength of the direct current passing through the solution, A;

t − the reaction time, s;

F − Faraday number, $9.648 \cdot 10^4$ Cl/mol;

n − the valence of the ion.

The weight of the electrode-active substance deposited on the electrode material is related to the geometry of the electrode itself:

$$m = S \cdot h \cdot Á, \quad (2)$$

where S − the cross-sectional area of the electrode surface, m^2;

h − thickness of the deposited layer of electrode-active material, m;

ρ − the density of the material, kg/m^3.

Further, applying formulas 1 and 2, the thickness of deposition of electrode-active material Ag2S as an ion-selective electrode of circular cross-section is calculated by the formula:

$$h = \frac{4A \cdot I \cdot t}{À \cdot d^2 \cdot Á \cdot F \cdot n}, \quad (3)$$

To compare the electrical characteristics of an ion-selective electrode, calculations are made of the thickness of deposition of electrode-active material on two types of electrodes:

– newly developed by the authors heterogeneous electrode of the 2nd kind d = 3.3 mm, U = 4 V, I = $1.5525 \cdot 10^{-3}$ A·s;

– silver wire from a standard factory-made electrode d = 1.8 mm; U = 1 V; I = 7.56·10-2 A·s.

The thickness of the ion-selective electrode of the first type is h1 = $0.05 \cdot 10^{-6}$ m, and in the second – h2 = $6.43 \cdot 10^{-6}$ m. The current density i_{01} = 1.8·10-2 A/mm^2, and i_{02} = 2.4 A/mm^2.

When optimizing the thickness of deposition of electrode-active material, the following formula for determining the application time is recommended:

$$t = \frac{S \cdot Á \cdot F \cdot h}{A \cdot I}, \quad (4)$$

For example, to obtain the electrode-active material of an ion-selective electrode of the first type with a thickness of 1 μm and I = 10^{-5} A·h, the application lasts about 30 minutes. With the increment of the current to I = 10^{-3} A·h the application time is sharply reduced to 32 s.

To a powder of silver with a particle size of 1-3 μm, thoroughly washed and dried, ED-20 epoxy resin with a curing agent was added in a ratio of 70% silver powder and 30% ED-20 by weight, thoroughly mixed until an electrically conductive mixture was obtained. The resulting mixture was formed into an electrode of the required size and the mixture solidified at 60°C. After solidification, the electrode surface was ground and washed with distilled water. The electrode was immersed in a 0.1 M solution of Na_2S and anodically polarized at a current density of $1.16 \cdot 10^{-7}$ A/mm^2 at normal temperature. In the process of polarization, the volume of the electrode-active substance of the electrode increases in comparison with the volume of the metal and a dense layer of electrode-active material forms in the pores of the matrix, which has the properties of an impermeable membrane for electrolyte.

The current density was chosen in such a way that a dense membrane was formed, the presence of which is indicated by the dependence of U(t) at a constant current strength (Fig. 2).

The obtained electrode has the following characteristics: a membrane thickness of about 10 μm, a membrane resistance of 1.4 MΩ.

Figure 2 shows the time dependence of deposition of electrode-active material with Ag2S-function at a constant current density of 6, 10, 20, 30, 40 $\mu A/mm^2$. With a low current density, the formation of a dense layer of electrode active substance in the pores of the matrix, which has the properties of an impermeable membrane, occurs slowly without detachment. With increasing current density, the formation of a dense layer occurs quickly and there is the possibility of detachment of the electrode active substance. Jumps on linear sections

Table 1

Comparative characteristics of electrodes

Electrode parameter	Analog	Prototype	In accordance with the developed criteria
Heating temperature of electrode material	100−350°C, sintering at 500°C	600−700°C, cooling at 450 °C	hardening at 60°C
Current Density	10 mA/cm^2	–	10^{-7}−10^{-8} A/mm^2
Layer Thickness	1.5 mm	0.15-0.3 mm	10 μm
Resistance of the electrode	–	–	1.4 MΩ
Preparation time	3,5 hours	4 minutes	20 minutes

arise due to a sharp decrease in the local resistance of the pores of the matrix.

After each application of the electrode active substance, the electrode was ground, washed with distilled water and a new layer was applied.

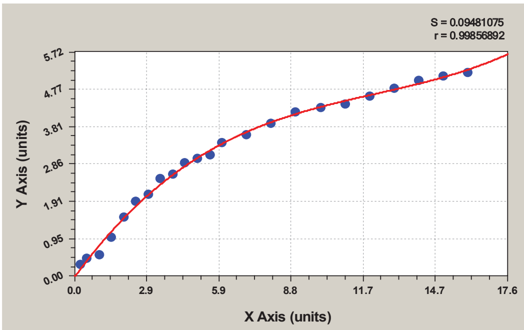
In the manufacture of an ion-selective electrode, the thickness of the electrode-active substance, the resistance of the electrode, and the polarization time can be classified as the main criteria for the parameters of anodic polarization.

The main developed mathematical models for manufacturing an ion-selective electrode using the example of a sulfide-selective measuring primary transducer are presented in Tables 2–6.

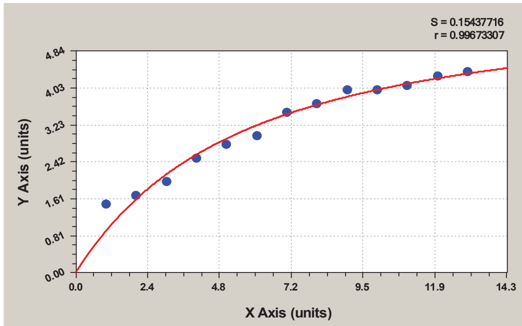
The ranking of mathematical models based on the correlation coefficient of experimental and calculated data on models based on one-parameter regression analysis is made. The standard error did not exceed 1.33%.

The main conclusions. The obtained results made it possible to solve an important scientific and technical problem of improving the quality of process water control by improving ionometric primary converters for automated control and measurement systems and to reveal a number of regularities in the course of anodic polarization of an electrode active substance on the surface of ion-selective electrodes in order to obtain rational parameters.

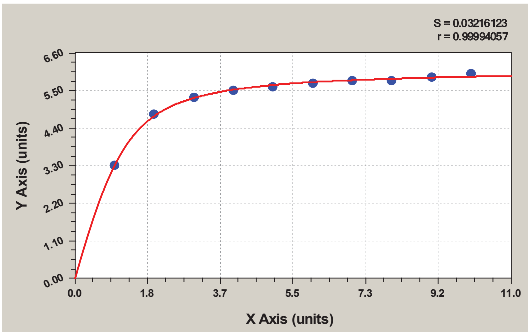
The developed methods of manufacturing an ion-selective electrode, mathematical and computer models have expanded the scientific and technical base for the design of ionometric primary converters.



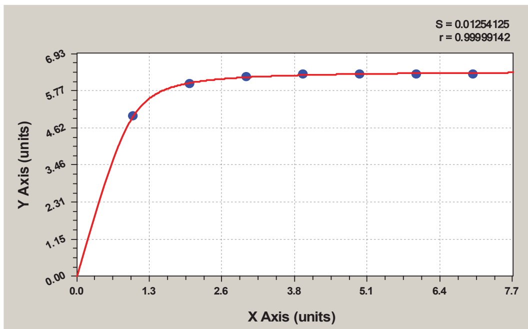
6 µA



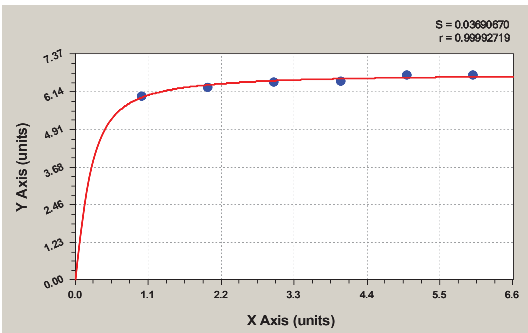
10 µA



20 µA



30 µA



40 µA

Fig. 2. Dependences of the voltage in the function versus time for depositing an electrode active material with an Ag2S function at a constant current density

Table 2

Regression models for current density of 6 μA/mm², which are ranked by the correlation coefficient. No weighting used

Rank	Model family	Model equation	Coefficient Data	Standard Error	Correlation Coefficient	Comments
1	3rd degree Polynomial Fit	$y = a + bx + cx^2 + dx^3 + \ldots$	a =-0.01586116 b =0.86107566 c =-0.058806944 d =0.0016020452	0.0948107	0.9985689	Linear regression completed successfully.
2	MMF Model	$y = \frac{ab + cx^d}{b + x^d}$	a =0.019879606 b =8.1890173 c =6.9249312 d =1.1387493	0.0951351	0.9985591	The fit converged to a tolerance of 10^{-6} in 5 iterations
3	Rational Function	$y = \frac{a + bx}{1 + cx + dx^2}$	a =-0.055183972 b =0.96626574 c =0.11753196 d =0.00039517782	0.1015502	0.9983581	The fit converged to a tolerance of 10^{-6} in 6 iterations
4	Exponential Association	$y = a(1 - e^{-bx})$	a =5.5742239 b =0.15396517	0.1024378	0.9981620	The fit converged to a tolerance of 10^{-6} in 4 iterations
5	Exponential Association (3)	$y = a(b - e^{-cx})$	a =5.5740591 b =1.0001888 c =0.15387804	0.1048476	0.9981620	The fit converged to a tolerance of 10^{-6} in 4 iterations
6	Quadratic Fit	$y = a + bx + cx^2$	a =0.20088066 b =0.64874041 c =-0.022001894	0.1782984	0.9946755	Linear regression completed successfully
7	Sinusoidal Fit	$y = a + b\cos(cx + d)$	a =-21.290935 b =26.272677 c =0.041880654 d =-0.61153839	0.1903512	0.9942190	The iteration count of 100 was exceeded. The fit failed to converge to tolerance of 10^{-6}
8	Logistic Model	$y = \frac{a}{(1 + be^{-cx})}$	a =4.8023304 b =6.9645473 c =0.48498216	0.3002328	0.9848278	The fit converged to a tolerance of 10^{-6} in 10 iterations
9	Harris Model	$y = \frac{1}{(a + bx^c)}$	a =9.8218183 b =-9.1914979 c =0.017465265	0.4949634	0.9582030	The iteration count of 100 was exceeded. The fit failed to converge to tolerance of 10^{-6}.
10	Linear Fit	$y = a + bx$	a =0.90896838 b =0.31497412	0.5088212	0.9536179	Linear regression completed successfully

Table 3

Regression models for current density of 10 μA/mm², which are ranked by the correlation coefficient. No weighting used.

Rank	Model family	Model equation	Coefficient Data	Standard Error	Correlation Coefficient	Comments
1	MMF Model	$y=\frac{ab+cx^d}{b+x^d}$	a =-0.16394022 b =17.188845 c =37.147937 d =0.71799244	0.2207596	0.9980936	The fit converged to a tolerance of 10^{-6} in 6 iterations.
2	Rational Function	$y=\frac{a+bx}{1+cx+dx^2}$	a =0.036261843 b =2.0483837 c =0.17644637 d =-0.0033832081	0.2363993	0.9978136	The fit converged to a tolerance of 10^{-6} in 7 iterations.
3	3rd degree Polynomial Fit	$y=a+bx+cx^2+dx^3+...$	a =0.32933613 b =1.4560054 c =-0.087617579 d =0.002415726	0.2896300	0.9967163	Linear regression completed successfully.
4	Exponential Association (3)	$y=a(b-e^{-cx})$	a =12.511854 b =1.0335835 c =0.1085052	0.3021628	0.9962464	The fit converged to a tolerance of 10^{-6} in 5 iterations.
5	Exponential Association	$y=a(1-e^{-bx})$	a =12.238764 b =0.12602876	0.3391006	0.9950444	The fit converged to a tolerance of 10^{-6} in 4 iterations.
6	Quadratic Fit	$y=a+bx+cx^2$	a =0.6561614 b =1.1358248 c =-0.032119198	0.3642924	0.9945394	Linear regression completed successfully.
7	Sinusoidal Fit	$y=a+b\cos(cx+d)$	a =-30.328437 b =40.969299 c =0.041213847 d =-0.71169611	0.3854227	0.9941775	The iteration count of 100 was exceeded. The fit failed to converge to tolerance of 10^{-6}.
8	Logistic Model	$y=\frac{a}{(1+be^{-cx})}$	a =10.424018 b =5.8725011 c =0.36596637	0.6405118	0.9830210	The fit converged to a tolerance of 10^{-6} in 6 iterations.
9	Linear Fit	$y=a+bx$	a =1.6898547 b =0.64858015	0.7834244	0.9732577	Linear regression completed successfully.
10	Harris Model	$y=\frac{1}{(a+bx^c)}$	a =4.8361121 b =-4.5075667 c =0.019039133	0.7838855	0.9744587	The iteration count of 100 was exceeded. The fit failed to converge to tolerance of 10^{-6}.

Table 4

Regression models for current density of 20 μA/mm², which are ranked by the correlation coefficient. No weighting used

Rank	Model family	Model equation	Coefficient Data	Standard Error	Correlation Coefficient	Comments
1	6th Degree Polynomial Fit	$y = a + bx + cx^2 + dx^3 + ...$	a =-0.00026301013 b =4.7007364 c =-1.6583053 d =0.30371593 e =-0.029421334 f =0.0013941569 g =-2.4090792·10^{-5}	0.0145844	0.9999896	Linear regression completed successfully.
2	MMF Model	$y = \frac{ab + cx^d}{b + x^d}$	a =-0.00013647068 b =0.81095251 c =6.0142513 d =1.6008303	0.0355067	0.9999276	The fit converged to a tolerance of 10^{-6} in 9 iterations.
3	Exponential Association	$y = a(1 - e^{-bx})$	a =5.8160629 b =0.83295724	0.0617889	0.9997587	The fit converged to a tolerance of 10^{-6} in 5 iterations.
4	Exponential Association (3)	$y = a(b - e^{-cx})$	a =5.8152515 b =1.0001448 c =0.83284239	0.0632392	0.9997587	The fit converged to a tolerance of 10^{-6} in 5 iterations.
5	Rational Function	$y = \frac{a + bx}{1 + cx + dx^2}$	a =-0.0011604014 b =6.5808316 c =0.89712839 d =0.012257261	0.0703891	0.9997153	The fit converged to a tolerance of 10^{-6} in 7 iterations.
6	Logistic Model	$y = \frac{a}{(1 + be^{-cx})}$	a =5.6026436 b =197.0093 c =5.6310533	0.2256205	0.9969244	The fit converged to a tolerance of 10^{-6} in 20 iterations.
7	Harris Model	$y = \frac{1}{(a + bx^c)}$	a =30.024989 b =-29.781903 c =0.0012000384	0.2337674	0.9966979	The iteration count of 100 was exceeded. The fit failed to converge to tolerance of 10^{-6}.
8	Quadratic Fit	$y = a + bx + cx^2$	a =0.15237316 b =1.8767609 c =-0.13812677	0.5920852	0.9786236	Linear regression completed successfully.
9	Sinusoidal Fit	$y = a + b\cos(cx + d)$	a =-46.669087 b =53.204628 c =0.072781952 d =-0.4946361	0.6165808	0.9779142	The iteration count of 100 was exceeded. The fit failed to converge to tolerance of 10^{-6}
10	Linear Fit	$y = a + bx$	a =0.55575221 b =0.73385358	1.2540217	0.8951165	Linear regression completed successfully.

Table 5

Regression models for current density of 30 μA/mm², which are ranked by the correlation coefficient. No weighting used

Rank	Model family	Model equation	Coefficient Data	Standard Error	Correlation Coefficient	Comments
1	MMF Model	$y=\frac{ab+cx^d}{b+x^d}$	a =$1.9039411\cdot10^{-6}$ b =0.26773449 c =6.3371565 d =2.2921148	0.0089030	0.9999957	The fit converged to a tolerance of 10^{-6} in 29 iterations.
2	Exponential Association	$y=a(1-e^{-bx})$	a =6.2921151 b =1.5731967	0.0107500	0.9999931	The fit converged to a tolerance of 10^{-6} in 5 iterations.
3	Exponential Association (3)	$y=a(b-e^{-cx})$	a =6.2920312 b =1.0000135 c =1.5731839	0.0110027	0.9999931	The fit converged to a tolerance of 10^{-6} in 5 iterations.
4	Rational Function	$y=\frac{a+bx}{1+cx+dx^2}$	a =$-6.1226843\cdot10^{-5}$ b =15.216919 c =1.981808 d =0.043803703	0.0234908	0.9999699	The fit converged to a tolerance of 10^{-6} in 6 iterations.
5	Logistic Model	$y=\frac{a}{(1+be^{-cx})}$	a =6.233345 b =7459.6947 c =10.316956	0.0590889	0.9998000	The fit converged to a tolerance of 10^{-6} in 17 iterations.
6	4th Degree Polynomial Fit	$y=a+bx+cx^2+dx^3+\ldots$	a =0.0044789762 b =7.1048486 c =-2.80422 d =0.45741233 e =-0.026232619	0.1072546	0.9994036	Linear regression completed successfully
7	Quadratic Fit	$y=a+bx+cx^2$	a =0.10675676 b =3.0881596 c =-0.33307593	0.6308206	0.9769383	Linear regression completed successfully.
8	Sinusoidal Fit	$y=a+b\cos(cx+d)$	a =-47.61032 b =54.88472 c =0.11134534 d =-0.51661143	0.6568767	0.9761754	The iteration count of 100 was exceeded. The fit failed to converge to tolerance of 10^{-6}.
9	Linear Fit	$y=a+bx$	a =0.41086957 b =1.1621118	1.3201111	0.8892869	Linear regression completed successfully

Table 6

Regression models for current density of 40 µA/mm², which are ranked by the correlation coefficient. No weighting used

Rank	Model family	Model equation	Coefficient Data	Standard Error	Correlation Coefficient	Comments
1	Rational Function	$y = \frac{a+bx}{1+cx+dx^2}$	a =-2.9852183·10^{-8} b =78.516962 c =12.199357 d =-0.11467602	0.0182087	0.9999823	The fit converged to a tolerance of 10^{-6} in 7 iterations.
2	Exponential Association	$y = a(1-e^{-bx})$	a =6.5486868 b =2.4133497	0.0663580	0.9997411	The fit converged to a tolerance of 10^{-6} in 6 iterations.
3	Exponential Association (3)	$y = a(b-e^{-cx})$	a =6.5485862 b =1.0000145 c =2.4133849	0.0679195	0.9997411	The fit converged to a tolerance of 10^{-6} in 6 iterations.
4	4th Degree Polynomial Fit	$y = a+bx+cx^2+dx^3+...$	a =0.0036766496 b =9.6037025 c =-4.777796 d =0.95773409 e =-0.066240565	0.1329116	0.9991025	Linear regression completed successfully.
5	Quadratic Fit	$y = a+bx+cx^2$	a =0.098122867 b =3.7423269 c =-0.46476719	0.6957476	0.9724521	Linear regression completed successfully.
6	Sinusoidal Fit	$y = a+b\cos(cx+d)$	a =-48.773534 b =56.41432 c =0.12974353 d =-0.52288064	0.7232289	0.9716386	The iteration count of 100 was exceeded. The fit failed to converge to tolerance of 10^{-6}.
7	Linear Fit	$y = a+bx$	a =0.35943775 b =1.4296902	1.3251651	0.8907820	Linear regression completed successfully.

A new method for manufacturing an ion-selective electrode was developed by applying an electrode active substance to a metal substrate, which was a current-conducting mixture of silver powder with a solid bonding dielectric, and an electrode-active substance was formed on the surface of the base by immersing the substrate in an electrolyte solution and anodic polarization at the current density in the range from 10-7 A/mm^2 to 10-8 A/mm^2.

Prospects for using the research results. The practical value of the work is to ensure the improvement of the accuracy of the process water quality monitoring by using the flow-injection analysis method, the development and improvement of the primary converters.

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