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CONDUCTOMETRIC SENSOR FOR DETERMINING THE CONCENTRATION OF IMPURITIES IN WATER

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Abstract

This paper examines the structure and operating principle of a conductometric cell, particularly the distribution of the electric field between the electrodes and the formation of the double electric layer. The analysis of the electrical equivalent circuit allows for a better understanding of the influence of various parameters on the overall conductivity of the system.

Keywords: conductometric cell, sensor, electrical conductivity, resistance.

Introduction. Conductometric measurements are one of the essential methods of electrochemical analysis, allowing the study of the conductivity of electrolyte solutions and the determination of their physicochemical properties. When an electric current passes through the solution in the cell, complex electrochemical and thermodynamic processes occur, defining the distribution of electric field lines, changes in ion concentrations, and the formation of a double electric layer. This report analyzes the relationship between the structure of the electrochemical system and its electrical characteristics, as well as presents the electrical equivalent circuit of the cell.

A conductometric cell [1] can be imagined as a coaxial capacitor with plate electrodes on both sides, ensuring a uniform flow of electric current. Through filling inlets, the chamber is filled with water (solution) that needs to be examined. The passage of electric current through the cell generates a chain of electrical and thermodynamic processes that take place not only inside the cell but also in the surrounding space. While no current is applied to the electrodes, the ions in the solution participate only in thermal motion. When the current is switched on, an electric field with intensity E is created in the cell, directing the ions' movement toward the electrodes and superimposing on the thermal motion.

Figure 1 presents a diagram of the distribution of electric field lines between two electrodes, showing that the current does not pass only through the shortest path from one electrode to another. Therefore, the resistance of the electrolyte in this cell is higher than its specific resistance.

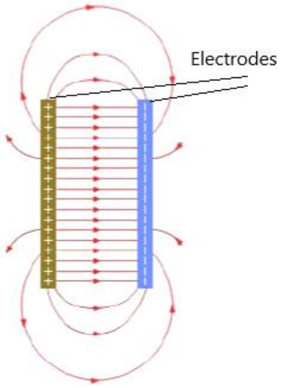

Fig. 1. Diagram of the distribution of electric field lines between the electrodes

When the electrode is immersed in the solution, the equality of the concentrations of cations and anions is disturbed because the electrode either releases its cations into the solution or attracts ions of a certain charge from the solution [2]. A platinum electrode causes a process in which metal cations from the solution deposit onto the electrode's surface, giving it a positive charge, while an excessive concentration of anions remains in a specific area of the solution. This process stops when an equilibrium potential jump is established, which prevents further charge growth. This state corresponds to a double electric layer (DEP), which in its simplest form consists of ions arranged in a single row. The electric field counters the thermal motion of the solvent molecules and ions, as well as the mutual repulsion of like ions. As a result of this double effect, the electric layer takes on a diffuse (blurry) character. The change in the concentrations of cations and anions occurs smoothly, approaching the equilibrium value.

The electrochemical circuit can be described based on a theoretical analysis of processes, creation of a physical model, and by constructing an electrical equivalent circuit using the simplest elements, primarily resistors and capacitors, and to a lesser extent inductors, which behave similarly to cells.

Electrode processes are difficult to represent solely with a combination of RLC elements, so it is necessary to use components with a nonlinear transfer characteristic, such as the Warburg impedance (ω), which corresponds to galvanic processes at the electrodes.

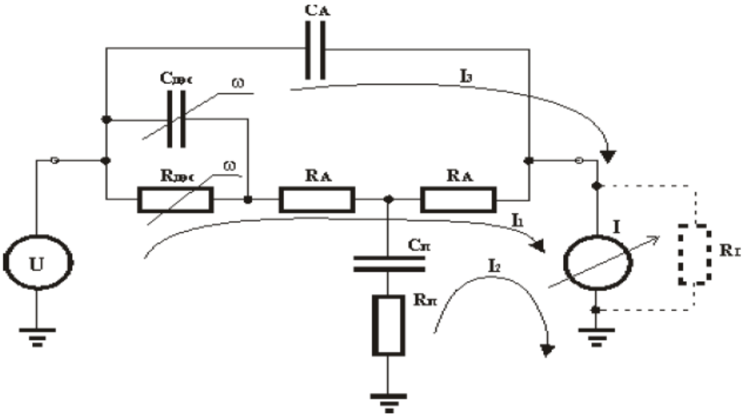

Fig. 2. Electrical diagram of the replacement of the conductometric cell

In Figure 2, the following symbols are used: C_a, R_a – intrinsic capacitance and active resistance of the liquid in the cell; C_{kx}, R_{kx} – electrical capacitance and active resistance related to electrode processes in the electrolyte, which depend on the frequency of the scanning signal; C_p, R_p – parasitic capacitance and active resistance of the measuring part of the conductometric cell; R_i – input resistance of the ammeter; U – signal generator; I – ammeter; I_1, I_2, I_3 – loop currents flowing through the individual sections of the equivalent circuit.

To calculate the electrical conductivity G using formula (1), the values of the loop currents I_1 and I_3 are used,

$$G = \frac{(I1(w) + I2(w)))}{U} \tag{1}$$

where I1(ω), I2(ω) – the loop currents in the respective sections of the equivalent circuit.

Conclusions. A detailed analysis of the electrochemical processes occurring in the conductometric cell was carried out. It was established that when alternating current passes through water in the conductometric cell, charge transfer processes occur, which are directly dependent on the concentration of ions in the solution. The electrochemical reactions reflect the interaction of impurity ions with the medium, which allows for the precise determination of their concentration. It was investigated that the alternating current creates a significant electromagnetic effect in the space around the conductometric cell. This effect enhances the interaction between ions, improving the sensitivity of the device in determining the concentration of impurities.

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КОНДУКТОМЕТРИЧНИЙ СЕНСОР ДЛЯ ВИЗНАЧЕННЯ КОНЦЕНТРАЦІЇ ДОМІШОК У ВОДІ

Анотація.

У даній роботі розглянуто будову та принцип дії кондуктометричної комірки, зокрема, особливості розподілу електричного поля між електродами та утворення подвійного електричного шару. Аналіз електричної еквівалентної схеми дозволяє краще зрозуміти вплив різних параметрів на загальну провідність системи.

Ключові слова: кондуктометрична комірка, сенсор, електропровідність, опір.

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