

*Original Contribution***IMPULSE APPROACH IN THE IDENTIFICATION OF ELECTROBIOLOGICAL CONDUCTIVITY CELL IN AGRICULTURAL CONDITIONS****K. Nikolov, N. Petrov***

Trakia University - St. Zagora, Technical College – Yambol

ABSTRACT

Bacterial contaminants in food mediums can give rise to measurable impedances and conductometry in electrical instruments. The most often used basic transformer is the conductometric twin-electrode cell. In this work the electrical processes in electrobiological conductometry was analysed; impulse approach was used in their identification.

Key words: polarization; identification; conductivity cell

INTRODUCTION

The impedance methods for express analysis of food mediums and in particular conductometry are the bases of a fact that bacterial metabolisms cause a change of the conductivity and dielectric permeability of the medium [1-5]. With increase in the number of the microorganisms, total admittance of the medium increases. This dependence is used for express determination of a growth of the microorganisms with respect to food medium. At low-impedance food mediums show polarization effects, which are the basic cause of origin of errors by measurement [6]. This characterizes the polarization of the electrodes in the cell: a time constant, electrical capacity and a resistance of the inter-phase surface “electrode-solution”. A model of the cell, showing an electrochemical chain with concentrated parameters is shown on **Figure 1**.

The supply suspense $E(t)$ is impulse and creates a relevant transitional process of the electricity. The form of $E(t)$ and the electricity in the chain are shown on **Figure 2**.

On **Figure 3** r_b is the resistance of the interior of the middle-electronic volume of

the solution; r_s - polarization resistance determining the delaying processes of current electricity; C_s - the capacity of the double electrical layer of the transition “electrode – solution”; l - distance between the electrodes with effective area S ; χ - specific electrical conductivity of the solution.

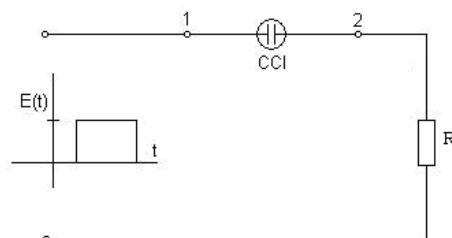


Figure 1. The scheme of the electrochemical chain with conductivity cell

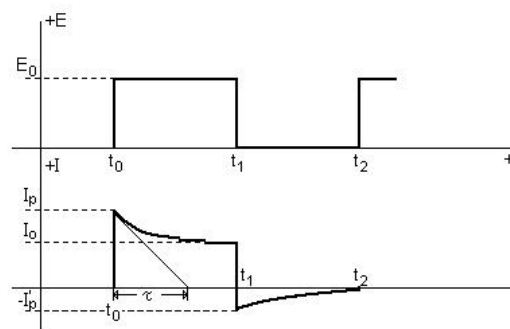


Figure 2. Time-diagrams of the transitional processes at the electrochemical chain

* Correspondence to: Nikolay Petrov, Trakia University - St. Zagora, Technical College Yambol; E-mail: nikipetrov@lycos.com

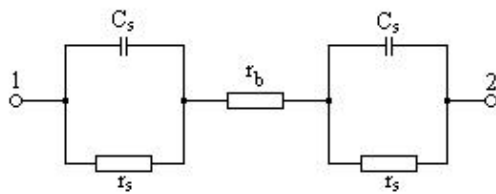


Figure 3. Equivalent substitutable scheme of conductivity cell

The leap value of the electricity I_p at the moment t_0 of passing of tension impulse with amplitude E_0 is determined by the directed movement of ions in the solutions, caused by the action of the electrical pole and is determined by the dependency:

$$(1) \quad I_p = \frac{E_0}{r_b + R_l} .$$

The process of flowing of the electricity after the moment t_0 is accompanied by forming a big ion charges, which conglomerate on the surface of the electrodes and cause a potential difference η of the double electrical layers at the passages “electrode-solution” [7, 8]. That causes a decrease of the potentials of the by-electrode layers of the solution and disrupts the process of pf flow of electricity through the inside of the between-electrode volume of the solution. The set regime is characterized by a permanent speed of the electro-chemical processes of the ion discharge on the surface of the electrodes at the relevant valuation of the polarization tension η :

$$(2) \quad I_0 = \frac{E_0 - \eta}{r_b + R_l} ,$$

where: I_0 is the set valuation of the electricity through the solution.

The valuation of the polarization tension η could be found through the decision of equation (1) and (2). That decision is shown with:

$$(3) \quad \eta = \frac{I_p - I_0}{I_p} \cdot E_0 .$$

Solving the problem:

Because of the exponential character of the transitional process, the flowing valuation of the electricity at the chain could be presented by equation:

$$(4) \quad I(t) = I_0 + (I_p - I_0) \cdot \exp\left(-\frac{t - t_0}{\tau}\right) = \frac{E_0 - \eta \{1 - \exp[-(t - t_0) \cdot 1/\tau]\}}{r_b + R_l}$$

where: τ is the time-constant of the examined chain; t - the flowing time of action of the impulse.

The flowing time t of action of the impulse is implemented by the statement:

$$(5) \quad t_0 \leq t \leq t_1 .$$

Determining the time-constant τ and realization of analysis of the processes of the turning on are executed by the following equivalent transformations of the chain, shown on **Figure 4a, b**.

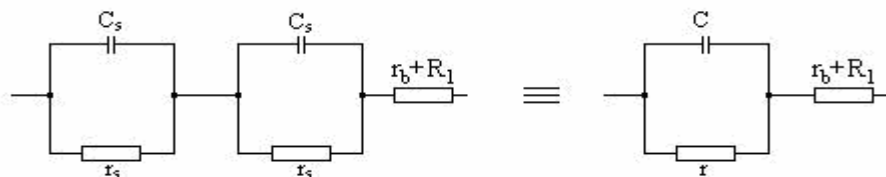


Figure 4a. Equivalent transformations at the scheme of the conductivity cell

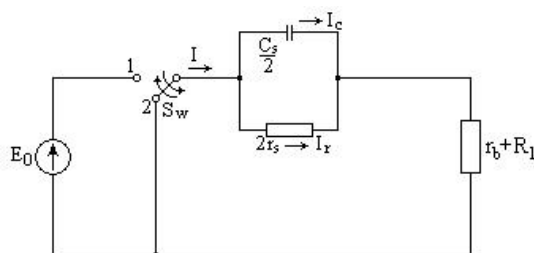


Figure 4b. The equivalent scheme of the communication at the conductivity cell

Figure 4b could be transformed as the following relations:

$$(6) \quad \frac{2r_s/C_s \cdot p}{r_s + 1/C_s \cdot p} = \frac{2r_s}{r_s C_s p + 1} = \frac{r}{r C_s p + 1} \Rightarrow r = 2r_s \Rightarrow C = \frac{C_s}{2}$$

According to the scheme, shown on **Figure 4b**, the determination of τ is done in the following way (key S_w at position 1):

$$7) \begin{cases} I = I_c + I_r \\ \frac{2}{C_s} \int I_c \cdot dt = 2I_r \cdot r_s \Rightarrow 2I_r \cdot r_s = E_0 - I \cdot R \Rightarrow I_r = \frac{E_0}{2r_s} - I \frac{R}{2r_s}, \\ 2I_r \cdot r_s + I \cdot r = E_0 \end{cases}$$

$$(8) \begin{cases} I = I_c + E_0/2r_s - I \cdot R/2r_s \\ \frac{2}{C_s} \int I_c \cdot dt = E_0 - I \cdot R \quad | \quad d/dt \Rightarrow \frac{2}{C_s} I_c = -\frac{dI}{dt} R \Rightarrow I_c = -\frac{C_s R}{2} \frac{dI}{dt}, \end{cases}$$

$$(9) \quad I = -\frac{RC_s}{2} \frac{dI}{dt} + \frac{E_0}{2r_s} - I \frac{R}{2r_s},$$

$$(10) \quad \frac{RC_s}{2} \frac{dI}{dt} + I \cdot \left(1 + \frac{R}{2r_s}\right) = \frac{E_0}{2r_s} \Rightarrow \frac{RC_s}{2} \frac{dI}{dt} + \frac{I \cdot (2r_s + R)}{2r_s} = \frac{E_0}{2r_s}.$$

Equation (10) can be transformed simply to:

$$(11) \quad Rr_s C_s \frac{dI}{dt} + (2r_s + R) \cdot I = E_0.$$

Equation (11) can be transformed in operator form, using the transformation $dI/dt \equiv p$, where we get:

$$(12) \quad Rr_s C_s \cdot p + 2r_s + R = 0 \Rightarrow p_1 = -\frac{2r_s + R}{Rr_s C_s}.$$

From the operator decision (12) follows the determination of the time-constant τ according to:

$$(13) \quad \tau = -\frac{1}{p_1} = \frac{Rr_s C_s}{2r_s + R} = \frac{C_s r_s \cdot (r_b + R_l)}{r_b + R_l + 2r_s}.$$

Therefore at the chosen substituted scheme of the conductivity cell (**Figure 3**) and the suggested equivalent scheme of the communication (**Figure 4b**), the time-constant τ will be determined by the equation:

$$(14) \quad \tau = \frac{C_s \cdot (r_b + R_l) \cdot r_s}{r_b + R_l + 2r_s}.$$

At disconnection of the supplying tension (commutation of the key S_w from position 1 to position 2) at the moment t_1 occurs discharge of the capacities C_s of the double electrical layers (**Figure. 5**) “electrode solution” occurs.

According to the principle of the permanency of the discharge concentrated on between-phase surfaces “electrode-solution” (C_s) at the moment of the communication t_1 is done, this condition applies:

$$(15) \quad 2U_{C_s} \cdot (t_1 + 0) = 2U_{C_s} \cdot (t_1 - 0) = \eta,$$

which helps in the valuation of the peak current I_p' determined by the equation:

$$(16) \quad I_p' = \frac{\eta}{R_l + r_b},$$

in that case from equation (2) the definite valuation of the electricity through the solution I_0 is obtained using:

$$(17) \quad I_0 = \frac{E_0 - \eta}{R_l + r_b} = \frac{E_0}{R_l + r_b} - \frac{\eta}{R_l + r_b}.$$

The set valuation of the electricity through the solution I_0 , corresponds to the permanent speed of the electrochemical processes of the ion charge on the surface of the electrodes, at definite valuation of the polarization tension η . Formula (17) is actual method of ensuring equality of the initial conditions of the transitional process at electro-biological (when $n=0$) at the same time as the pause time of the transitional process of conductivity cell, and is chosen by the condition:

$$(18) \quad \Delta t_0 > 3\tau.$$

CONCLUSION

From the identification of the transitional process at the electro-biological conductivity cell the following conclusions can be drawn:

The presented impulse method and model of the electrochemical processes at the conductivity cell gives the possibility for accomplishing of theoretical analysis of the

transitional processes, such as for experimental investigation of some of the main parameters (r_s , c_s , n) determined by the accuracy of the conductometric measurements of the biological mediums and solutions of the biological mediums and solutions.

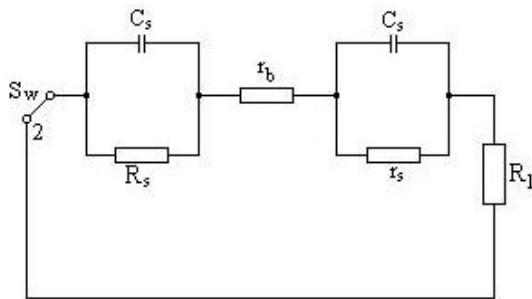


Figure 5. Discharge chain of the capacities of the double electrical layer

At preliminary chosen I_0 and η , the determination of the polarization resistance r_s , presented the resistance processes during the flow of electricity through the double layer “electrode-solution” and could be realized through the equation $r_s = \eta / 2I_0$ at which the polarization tension η is determined by $\eta = E_0 \cdot (I_p - I_0) / I_p$.

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