

# Current Density and Solution Flow-Through Rate Influence Upon the Dynamics of Copper Deposition onto Electrodes Made of Fibrous Carbon Materials

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## Abstract

Dynamics of electrolytic copper extraction from sulphuric acid electrolyte onto fibrous carbon electrodes with uniform distribution of initial electrical conductivity throughout the electrode thickness has been studied depending on the electrical conductivity of a fibrous carbon electrode, dimensional current density, the flow rate and the direction of solution feeding into the electrode as applied to the technology of copper extraction from the recovery bath of an automatic line of a galvanic manufacture.

**Key words:** fibrous carbon electrode, electrolysis, sulphuric acid solution, dynamics of copper deposition, current density, solution flow-through rate, deposit distribution

## INTRODUCTION

Galvanic manufacture is one of the basic consumers of the salts of nonferrous metals and, as a consequence, a source of wastewater containing toxic compounds of these metals. A considerable part of toxic metal ions enters into wastewater with washing solutions formed due to washing the products obtained after the operations of metallization, pickling, clarification, passivation, and etchings. Alongside with this a considerable amount of expensive reagents, including pure metal salts can be lost [1, 2]. An efficient method allowing one to neutralize simultaneously solutions, containing toxic compounds of metals as well as to utilize and reuse extracted metals consists in performing the electrolysis with cathodes made of fibrous carbon materials (FCM) [2–8, 9]. Electrolysis with fibrous carbon electrodes (FCE) is most efficient for the treatment of solutions containing metal ions with the concentration

amounting to several tens or several hundreds milligrams per litre. Such content of metal ions is just inherent in washing solutions.

The papers [2, 8, 9] validate and demonstrate a high efficiency of electrolysis with FCE in the process of metal extraction from washing solutions of a recovery bath of automated lines for metallizing workpieces as well as in the manufacture of circuit boards. Their use is promising since it provides solving the questions of environmental safety and resource economy in electroplating.

The conditions of electrolysis should provide the deposition of the highest possible amount of metal per FCM mass unit and a high efficiency of the process. The latter assumes the extraction of the metal introduced into a recovery bath with pieces under washing for the period between two consecutive washing procedures [2, 8, 9]. Due to the fact that the concentration of metal ions in the recovery bath is maintained at certain level (100–200 mg/L)

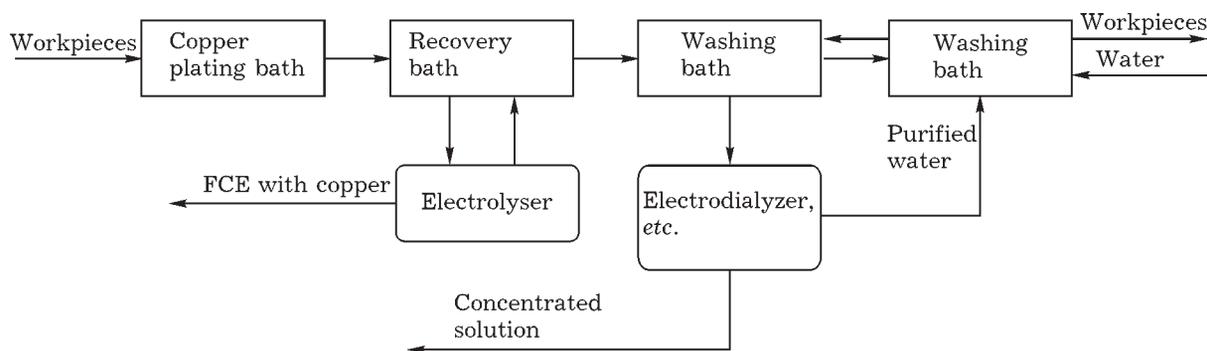


Fig. 1. Process flow diagram for electrolytic copper extraction from a recovery bath with closed cycle.

the metal current yield is high. The process flow diagram is presented in Fig. 1 [2, 8].

The major factors influencing the efficiency of the process are presented by FCM electrical conductivity, dimensional current density, rate and a direction of the solution flow rate through the bulk of an electrode, the electrode thickness. Studies on the effect of these factors as well as determining the scale of their influence upon parameters of the process represent one of the primary goals of the theory and practice of FCM application to the electrochemical deposition of metals from solutions.

The purpose of the present work consisted in studying the dynamics of electrochemical copper deposition onto electrodes made of FCM within a wide range of initial electrical conductivity of FCM composing an electrode depending on the current density, the rate and a direction of the solution flow rate through the electrode bulk (at the fixed electrode thickness) as applied to electrochemical copper extraction from solutions of the recovery bath of a galvanic manufacture automatic line, as well as in the estimation of changing the parameters describing the electrolysis process in time depending on the factors listed.

## EXPERIMENTAL

The scheme of performing the experiments simulates the process of metal electrolytic extraction from the solutions a recovery bath of galvanic manufactures [2, 8, 9]. The solution exposed to electrolysis with the composition of Cu 0.16,  $H_2SO_4$  25,  $(NH_4)_2SO_4$  80 (in g/L) and the volume amounting to 250 mL circulated between a tank with the solution (recovery bath)

and an electrolytic cell (electrolyser). The specific electrical conductivity of the solution was equal to 0.101 Sm/cm.

The constant concentration of ions of the metal under extraction in the tank maintained within a certain narrow range ( $0.16 \pm 0.03$  g/L) was provided via the addition of a certain volume of the basic copper-plating electrolyte with the composition of Cu 15,  $H_2SO_4$  25,  $(NH_4)_2SO_4$  80 (in g/L) every 5–15 min depending on the rate of copper extraction. The total volume of electrolyte in the experiment remained constant. The concentration of copper ions in the solution was determined employing the method of direct voltammetry with the use of a renewable graphite microelectrode [10].

We studied electrochemical copper extraction for electrodes with constant initial electrical conductivity all over the thickness depending on the dimensional current density (500–2500 A/m<sup>2</sup>), flow-through rate of the solution amounting to 0.1–1.0 mL/(s · cm<sup>2</sup>), initial electrical conductivity of FCM composing the electrode equal to  $(1.8 \cdot 10^{-6} - 4.6 \cdot 10^{-1})$  Sm/cm).

Electrochemical copper deposition was carried out under galvanostatic conditions. Cathodic polarization was performed using a B5-47 direct current power supply. The scheme of the electrolytic cell is described in [3, 4]. The cathode was 6 mm thick; it consisted of five FCM layers, the anode represented a platinum wire, the lead represented a plate made of punched titanium covered with a thin layer of copper. We used the model of back solution feeding into the electrode with a backside lead. The side of the electrode adjoining to the punched lead was denoted as a backside, whereas that being nearby to the anode was considered as a

frontal side. The electrode thickness was determined basing on a possible electrode stack consisting of five layers being close to the highest possible electrode thickness used in the industry [2, 4, 6–9].

The parameters of FCM employed for composing are presented in Table 1. The methods for determining the values of specific electrical conductivity  $\kappa$ , reaction surface area  $S_r$  and porosity  $\varepsilon$  are described in [4]. The basic attention in choosing the materials was given to their specific electrical conductivity.

Each FCM layer composing the electrode was weighed using analytical balance before and after electrolysis within the accuracy of 0.0001. After electrolysis, the electrode was washed with distilled water being dried then in a drying oven at the temperature of 80 °C to obtain constant mass. The mass of metal deposited was determined from the difference in FCM mass before and after electrolysis.

The ratio between the mass of copper deposit to the mass of FCM for each layer was calculated according to the formula:  $d = m_{Cu}/m_{FCM}$ ; the ratio between the total deposit mass and the mass of entire FCM was calculated according to the formula

$$\Delta = \sum_{i=1}^5 m_{Cu\_i} / \sum_{i=1}^5 m_{FCM\_i}$$

Here  $m_{Cu\_i}$  is the mass of metal deposited onto one layer of the electrode, g;  $m_{FCM\_i}$  is the mass of the FCM layer before electrolysis. Alongside with these, the rate of copper deposition was calculated in the following manner:

$$U = m_{Cu}/(\tau S_{el})$$

Thus the current yield of copper (CY) for total electrolysis time can be expressed as

$$CY = \sum_{i=1}^5 m_{Cu\_i} F / (JM_{eq}\tau)$$

where  $\sum_{i=1}^5 m_{Cu\_i}$  is the total mass of copper, deposited onto entire electrode, g;  $\tau$  is electrolysis time, h;  $S_{el}$  is the sectional area of the electrode, cm<sup>2</sup>;  $F$  is the Faraday number;  $J$  is the intensity of current, A;  $M_{eq}$  is the molar mass of copper equivalent, g/mol.

In order to estimate the uniformity of metal distribution over the thickness of FCE we used a commonly known criterion such as the root-mean-square deviation [11] which was calculated according to the formulas

$$m_{Cu\_av} = 1/5 \sum_{i=1}^5 m_{Cu\_i}$$

$$H_{RMS} = \sqrt{1/5 \sum_{i=1}^5 (m_{Cu\_i} - m_{Cu\_av})^2}$$

Here  $m_{Cu\_av}$  is the average mass of copper, deposited onto the FCM layer, g;  $m_{Cu\_i}$  is the mass of copper on each FCM layer, g. All the calculations were performed with the use of Microsoft Office Excel 2007.

## RESULTS AND DISCUSSION

The efficiency of the process of metal electrochemical deposition onto FCE depends on the properties of the electrode – solution system, the conditions of electrolysis, the electrode system design. In this connection, it is important to establish the influence of the factors listed upon the process parameters for metal electrochemical deposition onto FCE.

TABLE 1

Characteristics of carbon fibrous materials

Material	$\kappa$ , Sm/cm	$r$ , $\mu$ m	$S_p$ , cm <sup>2</sup> /cm <sup>3</sup>	$\varepsilon$	Density, g/cm <sup>3</sup>
VNG-50	0.46	6.0	280	0.92	0.169
VINN-250	0.1	4.5	270	0.94	0.110
ANM	$1.5 \cdot 10^{-2}$	6.1	311	0.91	0.152
KNM-450	$1.8 \cdot 10^{-6}$	6.1	250	0.92	0.115
Carbonetkalon TK-24	0.41	3.5	750	0.87	0.265

Note.  $\kappa$  is specific electric conductivity of FCM;  $r$  is the radius of fibres composing the FCM;  $S_p$  is the reactionsurface area;  $\varepsilon$  is porosity.

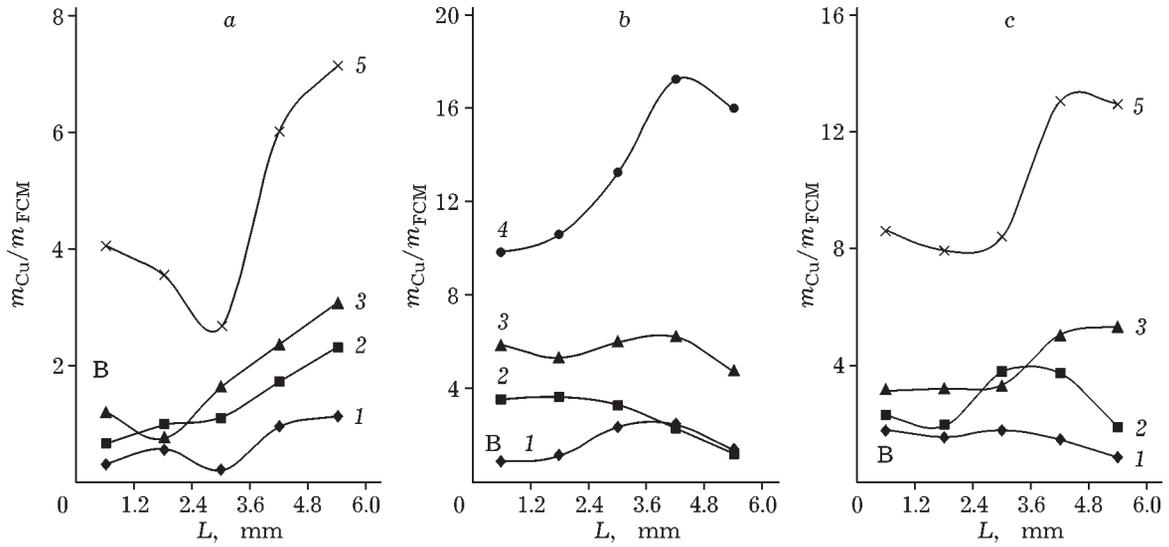


Fig. 2. Copper mass to FCE mass ratio ( $m_{Cu}/m_{FCM}$ ) depending on the electrode thickness at the dimensional current density 500 (a), 1500 (b) and 2500  $A/m^2$  (c). Duration of electrolysis, min: 60 (1), 120 (2), 180 (3), 390 (4), 420 (5); B is electrode backside; FCM is presented by VNG-50.

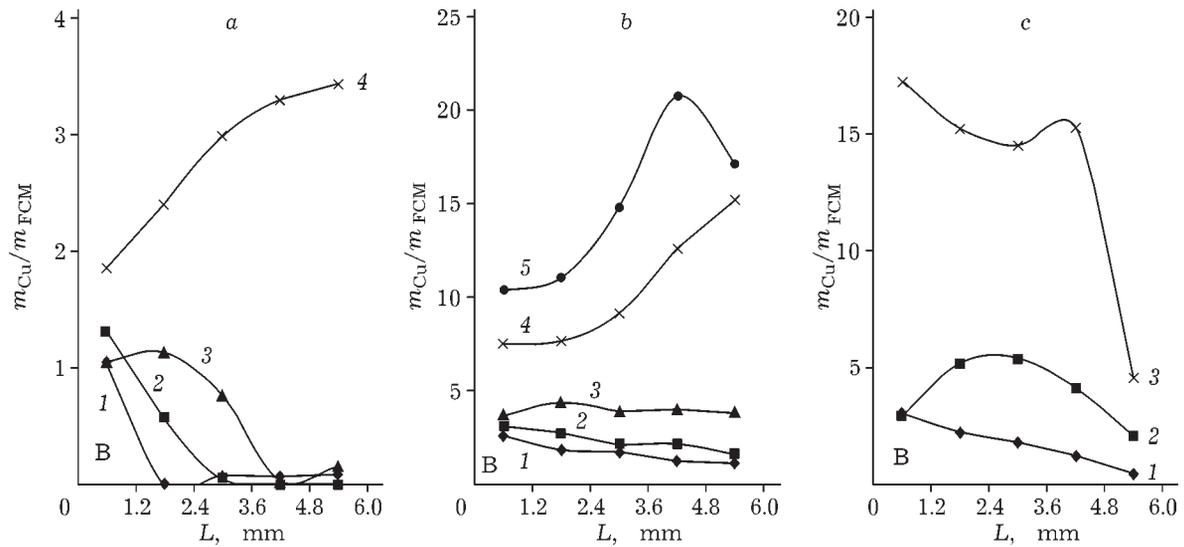


Fig. 3. Copper mass to FCE mass ratio ( $m_{Cu}/m_{FCM}$ ) depending on the electrode thickness at the dimensional current density 500 (a), 1500 (b) and 2500  $A/m^2$  (c). Duration of electrolysis, min: 60 (1), 120 (2), 180 (3), 420 (4), 540 (5); B is electrode backside; FCM is presented by ANM.

**Effect of initial FCE conductivity**

Figures 2 and 3 demonstrate the results of studying the dynamics of copper deposit distribution over electrode thickness for FCM with high and low initial electrical conductivity, respectively, at different values of the dimensional current density. Similar results were obtained for the electrodes made of all the FCM presented in Table 1.

The analysis of the results has demonstrated that the process of electrolysis results in

changing the distribution of copper deposit over the electrode thickness inherent in each kind of FCM. At short electrolysis times and at the dimensional current density amounting to 1500 and 2500  $A/m^2$  metal is distributed over the electrode thickness in a relatively homogeneous manner. An increase in electrolysis time till the moment characterizing the “saturation” of the electrode with metal (a considerable decrease in the solution flow rate through the electrode or ceasing the solution flowing-through), can considerably change the “picture” of metal

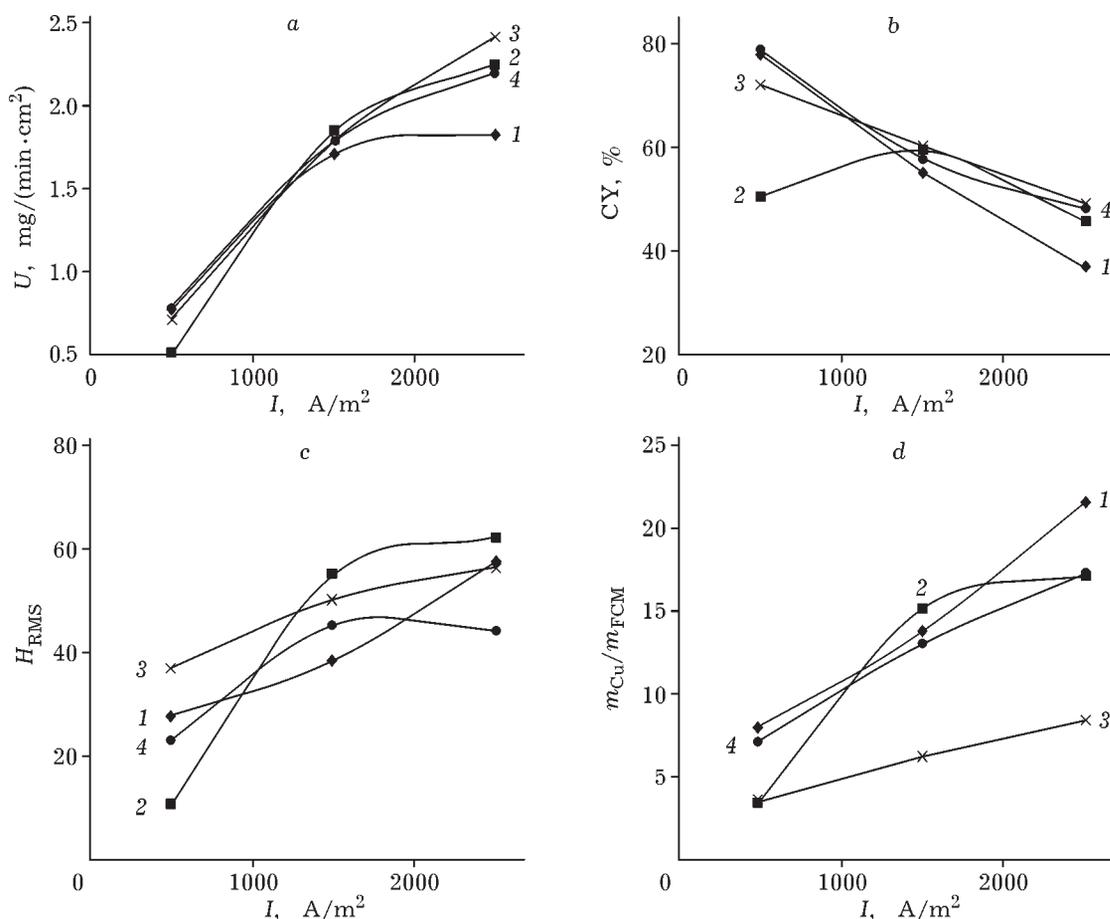


Fig. 4. Changing in the copper extraction rate  $U$  (a), the current yield of copper  $CY$  (b), root-mean-square deviation  $H_{RMS}$  (c) and the ratio between the mass of deposited copper and the mass of electrode  $m_{Cu}/m_{FCM}$  (d) during the electrochemical extraction of copper, depending on the dimensional current density ( $i$ ) for various FCM: KNM-450M (1), ANM (2), Carbonetkalon TK-24 (3), VNG-50 (4). Electrolysis time, min: 420 (1, 2, 4) and 330 (3).

distribution over the electrode thickness as well as the parameters of the electrolysis process.

Figure 4 demonstrates plots of varying the basic parameters of the process of electrochemical copper extraction depending on the dimensional current density for various FCM. These data concern the time of electrolysis determining the electrode "saturation" by metal, representing the integrated characteristics of experimental data. It is seen that at the dimensional current density amounting to 500 and 2500  $A/m^2$  the parameters of the process differ to a considerable extent. A similar picture can be seen at the initial stage of electrolysis (less than 30 min) for all the values of dimensional current densities under investigation.

Within the range of the dimensional current density values of 1000–1500  $A/m^2$ , irrespective of specific electrical conductivity and

the reaction surface area of the material, we have obtained sufficiently close values of  $CY$ ,  $U$ ,  $m_{Cu}/m_{FCM}$  and  $H_{RMS}$  for all the FCM under consideration. Employing a calculation method with the use of known equations [3, 4, 12] it has been demonstrated that the dimensional current density of  $(1250 \pm 200) A/m^2$  results in the fact that the electrochemical copper deposition occurs with the limiting diffusion current for all (or almost all) the electrode thickness, which, to all appearance, causes the character of curves presented in Fig. 4.

Data presented in Fig. 2, a, 3, a and 4, indicate that the individual properties of FCM (its specific electrical conductivity and the reaction surface area) are most distinctly exhibited at small current density values.

The character of copper deposition onto fibres of FCM is presented in electron microscopic

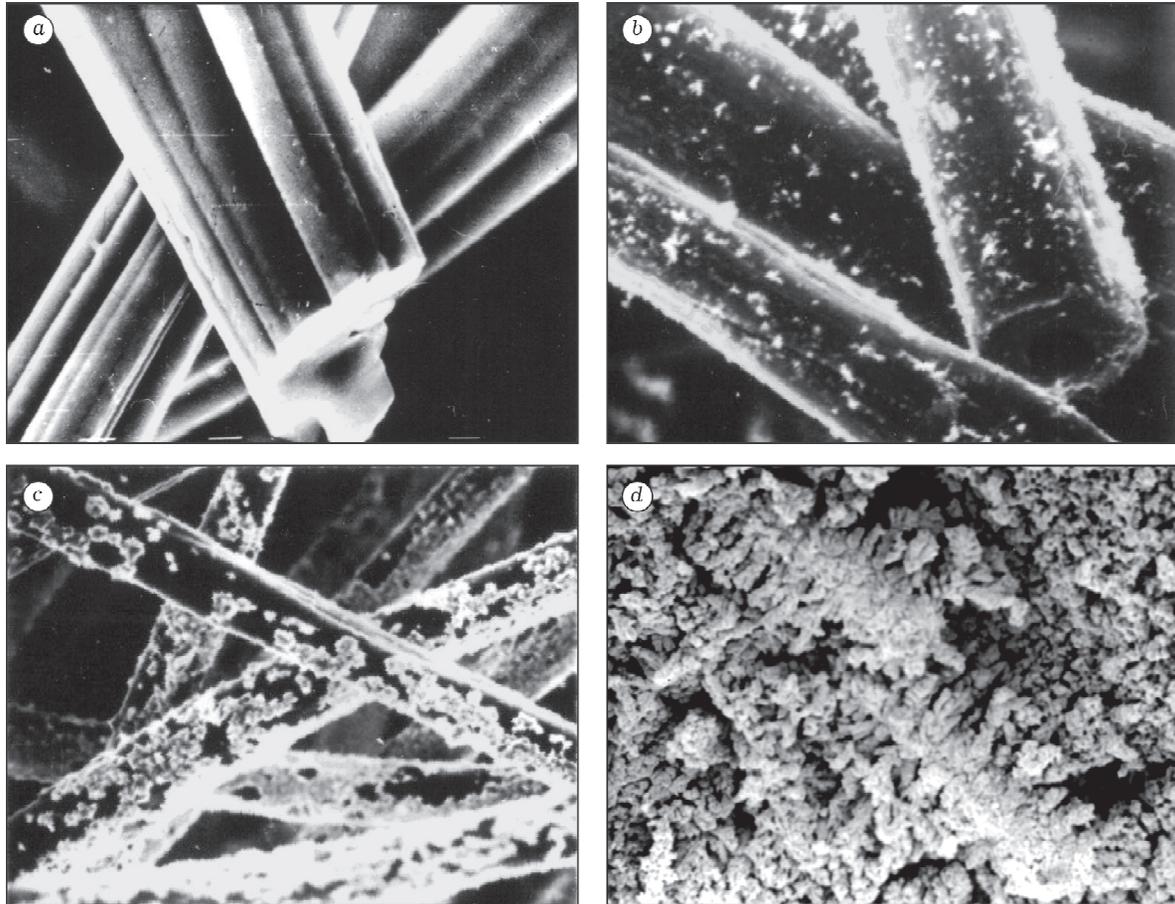


Fig. 5. Photomicrographs for FCM samples: *a* – before electrolysis (magn. 2500), *b–d* – with deposited copper after electrolysis for 5 min (*b*, magn. 2500), 60 min (*c*, magn. 1000) and 420 min (*d*, magn. 350).

images (Fig. 5) obtained with the help of JSMT-20 scanning electron microscope. It is seen that at the initial stage of electrolysis, on the surface of FCM fibres there are nuclei formed those gradually increase in size and overlap among themselves forming continuous highly conductive layer of a metal deposit. Alongside with this, growing metal islands filling the space between fibres overlap to form additional path-

ways for current flowing. As a consequence, the electrical conductivity of separate parts of the electrode increases and, finally, the same event happens to the electrode as a whole. The electrical conductivity of the electrode to a considerable extent exceeds the electrical conductivity of the solution, which results in changing the character of copper deposit distribution over the electrode thickness. According to

TABLE 2

Parameters of copper electrochemical deposition onto electrodes made of FCM. Dimensional current density being equal to  $1500 \text{ A/m}^2$ , the solution flow-through rate being of  $0.4 \text{ mL}/(\text{s} \cdot \text{cm}^2)$

Material	$U$ , $\text{mg}/(\text{min} \cdot \text{cm}^2)$	CY, %	$\delta_{\text{max}}$	$\delta_{\text{av}}$	$H_{\text{RMS}}$	$\tau$ , min
VNG-50	1.8	57.9	13.06	10.34	45.4	420
VINN-250	2.1	68.1	27.46	12.54	106.1	420
ANM	1.8	59.3	15.18	10.56	55.1	420
KNM-450M	1.7	55.4	13.75	9.81	38.5	420
Carbonetkalon TK-24	1.8	60.3	6.21	3.66	50.2	330

the experimental data we have obtained earlier, the formation of continuous deposit which provides high electrical conductivity of the electrode is observed with the deposition of about 1–2 g/g of FCM for the “island” structure of the deposit and more than 0.2 g/g of FCM in deposition of a deposit in the form of a thin film. The relative mass of copper deposited onto various layers of the electrode, does not exceed 3 g/g of FCM for the period less than 120 min of electrolysis. Further, this ratio exceeded 3 g/g of FCM to cause forming an electrode with high electrical conductivity.

Table 2 demonstrates integrated parameters concerning the time of electrolysis determining the “saturation” of the electrode with metal. These parameters characterize the process of copper deposition onto electrodes made of the FCM under investigation: the process rate ( $U$ ), the current yield of copper (CY), the relative mass of copper deposited onto one layer of the electrode ( $\delta$ ), the root-mean-square deviation  $H_{\text{RMS}}$ . One can see that the most non-uniform distribution of copper deposit is observed for the electrode made of VINN-250 with high electrical conductivity wherein the maximal value of ( $H_{\text{RMS}}$ ) is registered; as much as 27.5 g copper was deposited onto 1 g of FCM (which corresponds to one layer). Copper is distributed most uniformly over the electrode made of FCM with low electrical conductivity (KNM-450M),  $H_{\text{RMS}} = 38.5$ . As much as 13.75 g of copper was deposited onto 1 g of FCM (one layer). As far as an electrode made of highly conductive material (Carbonetkalon TK 24) with a lower porosity and the highest density, a minimum amount of metal deposited onto the mass unit of material was obtained, and there was a minimal time required for overstocking the electrode with metal.

#### *Effect of solution feeding direction*

The direction of feeding the solution into the electrode influences to a considerable extent upon the parameters of the process of electrochemical copper deposition. With changing the direction of feeding the solution into the electrode from back to frontal one, copper is deposited onto the side of solution feeding

during all the time of electrolysis. With increasing the initial electrical conductivity of the electrode material from  $1.3 \cdot 10^{-2}$  Sm/cm (ANM) up to  $4.6 \cdot 10^{-1}$  Sm/cm (VNG-50) the time of electrode “saturation” with metal decreases amounting to 180 min for ANM and only 90 min for VNG-50. The ratio between the mass of a copper deposit and the mass of the layer varies ranging within 6–9 g/g of FCM. The current 30–40 %. Thus, the electrochemical copper deposition onto FCE with the frontal solution feeding into the electrode under the electrolysis process conditions under investigation is characterized by a rather low efficiency, which does not allow us to recommend this mode for industrial application.

#### *Influence of solution flow-through rate*

One of the important technological parameters allowing one to influence the process of the electrochemical extraction of metals from the recovery bath of galvanic manufacture automatic lines is presented by solution flow rate through the bulk of the electrode (or the rate of solution circulation between electrolyser and washing bath). According to theoretical concepts concerning the operation of flow-through bulk-porous electrodes, the electrochemical process is located at the side of feeding the solution into the electrode ( $K_m S \gg m_v$ ) or it is uniformly distributed over the electrode thickness ( $K_m S \ll m_v$ ) depending on the ratio between  $K_m S$  and  $m_v$  ( $K_m$  is mass transfer factor,  $S$  is reaction surface FCE,  $m_v$  is solution flow-through volume rate) [13].

In this case the author of [13] assumes that the discharge of an electroactive component occurs with the limiting diffusion current all over the volume of the electrode, whereas the electrical conductivity of the electrode material is much greater than the electrical conductivity of the solution. He did not specify, how many times  $K_m S$  is higher or lower than  $m_v$ . Moreover, the situations when either  $K_m S > m_v$  or  $K_m S < m_v$ , or their values are comparable were not considered, let alone the situation when the discharge of electroactive component occurs out of the limiting diffusion current mode or at higher current density values. In

addition, the influence of the ratio between these parameters upon the distribution of electroactive component discharge over the electrode thickness under gradual “overgrowing” the FCE with metal, *i. e.* in dynamics when the ratio of these components is changing, appeared to be with no consideration.

In connection with the foregoing, it is of practical and theoretical interest to investigate experimentally the influence of the solution flow-through rate upon the efficiency of metal electrochemical deposition onto FCE in dynamics. The range of solution flow rate values chosen amounts to 0.1–1.0 mL/(s · cm<sup>2</sup>). The studies were carried out at fixed values of the dimensional current density such as 500, 1500 and 2500 A/m<sup>2</sup> for electrodes made of ANM, VINN-250 and VNG-50.

Let us in more detail consider the results obtained for the electrodes made of ANM and VNG-50 at the dimensional current density equal to 1500 A/m<sup>2</sup>.

Table 3 demonstrates the results of calculations for  $K_m S$  depending on  $m_v$ , performed according to [13], for the rates of solution flow-through realized in the industry. Within entire range under investigation,  $K_m S > m_v$  for all the materials listed in Table 1. As far as different materials are concerned, the values of  $K_m S$  vary within a narrow range at the same solution flow-through rate.

TABLE 3

$K_m S$  value depending on linear solution flow-through rate, determined *via* a calculation method

Material of electrode	Flow-through rate, mL/(s · cm <sup>2</sup> )				
	0.01	0.1	0.4	1.0	3.0
VNG-50	1.1	2.4	3.9	5.3	9.4
VINN-250	1.0	2.3	3.7	5.1	9.1
ANM	1.2	2.6	4.3	5.9	10.4
KNM-450M	0.9	2.1	3.5	4.8	7.1

As it was indicated above, the dimensional current density of 1500 A/m<sup>2</sup> and the flowing-through rate equal to 0.4 mL/(s · cm<sup>2</sup>) result in the fact that at a considerable part of the electrode the ions of copper are reduced in the mode of the limiting diffusion current. It is obvious that at the flow-through rate amounting to 0.1 mL/(s · cm<sup>2</sup>) the discharge of copper ions should be accompanied by a considerable hydrogen evolution, whereas at the rate equal to 1.0 mL/(s · cm<sup>2</sup>) the reduction of copper ions in the limiting diffusion current mode is possible for a small part of the electrode.

Figures 6, 7 present the results for the studies on the dynamics of copper deposit distribution over the thickness of electrodes made of materials with low (see Fig. 6) and high (see Fig. 7) initial electrical conductivity at different values of the solution flow rate and at the dimensional current density equal to 1500 A/m<sup>2</sup>. It

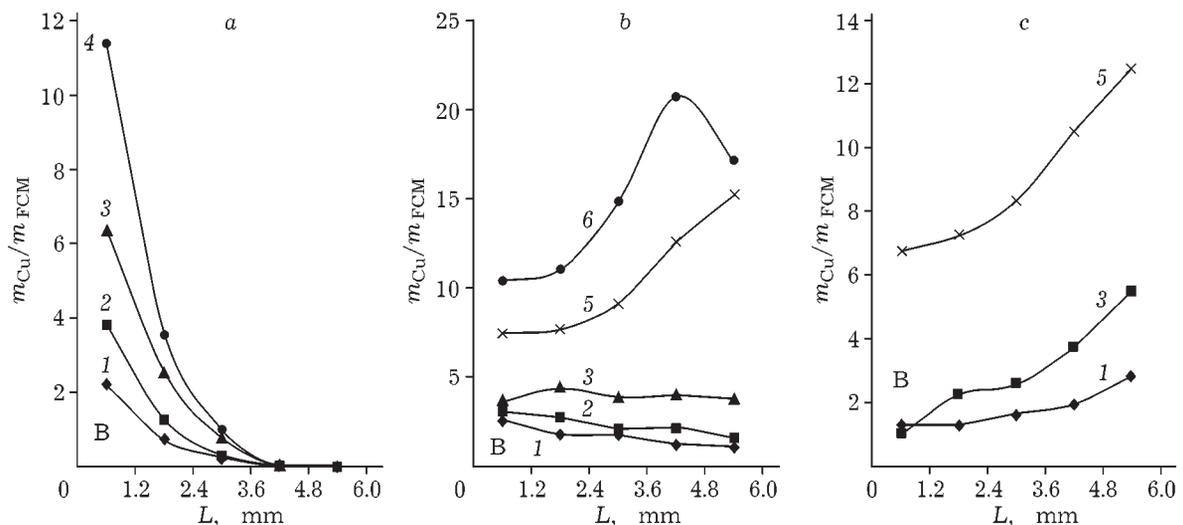


Fig. 6. Copper mass to FCE mass ratio ( $m_{Cu}/m_{FCM}$ ) depending on the electrode thickness at the solution flow-through rate 0.1 (a), 0.4 (b), 1.0 mL/(s · cm<sup>2</sup>) (c). The duration of electrolysis, min: 60 (1), 120 (2), 180 (3), 360 (4), 420 (5), 540 (6); B is electrode backside; FCM is presented by VNG-50.

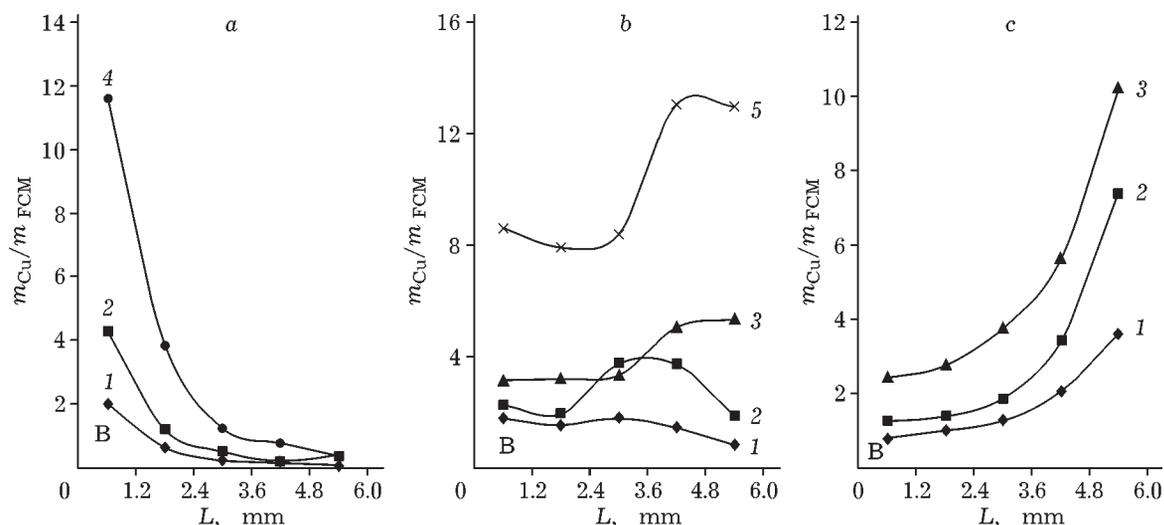


Fig. 7. Copper mass to FCE mass ratio ( $m_{Cu}/m_{FCM}$ ) depending on the electrode thickness at the solution flow-through rate 0.1 (a), 0.4 (b), 1.0 mL/(s · cm<sup>2</sup>) (c). The duration of electrolysis, min: 60 (1), 120 (2), 180 (3), 360 (4), 420 (5), 540 (6); B is electrode backside; FCM is presented by ANM.

is seen that an increase in the flow-through rate from 0.1 to 1.0 mL/(s · cm<sup>2</sup>) results in changing the localization of the main part of copper deposit. A similar character of changing the distribution of copper deposit over the electrode thickness depending on the solution flow-through rate has been obtained at the dimensional current density values amounting to 500 and 2500 A/m<sup>2</sup>.

The rate of copper deposition and its current yield exhibit an increase with the increase in the solution flow-through rate in the case of VNG-50 for all the dimensional current density values under investigation, whereas in the case ANM this phenomenon is observed at 1500 and 2500 A/m<sup>2</sup> (Fig. 8). These data were obtained

under the conditions those are close or corresponding to so called "saturation" of an electrode with metal. At a slow flow-through rate of the solution (0.1 mL/(s · cm<sup>2</sup>)) the values of copper deposition rate (see Fig. 8, a) and the ratio between the mass of copper the mass of the electrode (see Fig. 8, c) are close to a considerable extent. With an increase in flow-through rate of the solution one can reveal a discrepancy between them. A maximal value of copper mass deposited onto the electrode in total at the flow-through rate amounting to 0.4 mL/(s · cm<sup>2</sup>) is observed at 1500 both 2500 A/m<sup>2</sup>, as well as its decrease is registered for the dimensional current density equal to 500 A/m<sup>2</sup>

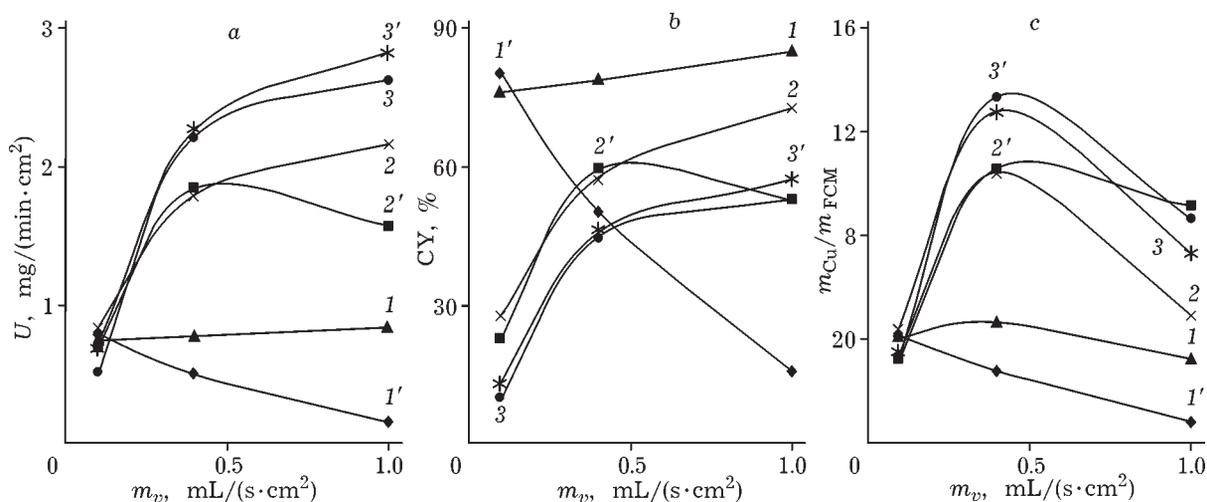


Fig. 8. Copper extraction rate  $U$  (a), copper current yield  $CY$  (b) and copper mass to FCE mass ratio  $m_{Cu}/m_{FCM}$  (c) depending on the solution flow-through rate: 1-3 - VNG-50; 1'-3' - ANM;  $i$ , A/m<sup>2</sup>: 500 (1, 1'), 1500 (2, 2'), 2500 (3, 3').

(see Fig. 8, c). With increasing the solution flow-through rate, the ratio  $m_{\text{Cu}}/m_{\text{FCM}}$  decreases, and this fact most pronounced for the electrode made of the material with a low electrical conductivity (ANM).

The aforementioned results of the experimental studies demonstrate that theoretical premises concerning the distribution of the electrochemical process over the electrode thickness depending on the ratio between  $K_m S$  and  $m_v$  under the conditions of real electrochemical deposition of metal onto FCE have not obtained any practical support. So, the electrochemical deposition of metal onto FCE under real conditions considered in our work, does not occur all over the bulk of the electrode in the case of the limiting diffusion current; the initial electrical conductivity of FCM does not exceed to a considerable extent the electrical conductivity of the solution (especially during the initial phase of electrolysis); in the course of the electrochemical deposition of metal, changing is observed concerning the ratio between  $K_m S$  and  $m_v$ , as well as the ratio between the electrical conductivity values corresponding to the electrode material and the solution. The electrochemical metal deposition is usually accompanied by parallel reactions of hydrogen ion and oxygen reduction. To all appearance, just the combination of these causes is determining for the considerable discrepancy between the results of experimental research and theoretical forecasts.

## CONCLUSION

The dynamics electrolytic copper extraction from sulphuric acid solution was studied for the following composition, g/L: Cu 0.16, H<sub>2</sub>SO<sub>4</sub> 25, (NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub> 80 deposited onto fibrous carbon electrodes (FCE) with uniform distribution of initial electrical conductivity over the electrode thickness depending on the initial electrical conductivity of the electrode ( $0.46\text{--}1.8 \cdot 10^{-6}$  Sm/cm), the dimensional current density (500–2500 A/m<sup>2</sup>), the flow rate solution feeding (0.1–1.0 mL/(s · cm<sup>2</sup>)) into the electrode as applied to the technology of

copper extraction from a recovery bath of galvanic manufacture automated line.

It has been established that in the course of electrochemical deposition, the profile of copper deposit over the electrode thickness inherent in each set of electrolysis conditions and in the kind of FCE exhibits changing. Thereof the parameters describing the process of electrochemical copper deposition (the current yield of copper, the rate of copper deposition, the uniformity of distribution over the electrode thickness, the specific mass of copper deposited onto FCE) exhibit changing, too. The prevailing effect on the dynamics of deposit distribution over the electrode thickness and the parameters of electrochemical deposition process under the investigated electrolysis conditions is exerted by the solution flow-through rate and the dimensional current density. It has been established that the initial electrical conductivity of FCM influences to a lesser extent and its influence is most pronounced at low electrolysis duration time and low dimensional current density.

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