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Electrolysis with Carbon-Graphite Flow Electrodes for Solving Problems of Precious Metal Extraction from Jewellery Manufacturing Wastes

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Abstract

The possibility of using electrolysis with carbon-graphite flow electrodes of fibrous carbon materials for recovery of gold and silver from solutions formed at various stages of jewellery manufacturing is considered. It is demonstrated that electrolysis with carbon fibrous electrodes ensures high (more than 99 %) degree of gold and silver extraction: 1) from sulphuric acid – thiourea solutions of anodic etching of golden articles with any gold content, 2) from washing solutions and waste electrolytes of gold and silver plating of jewellery articles, 3) from solutions that result from hydrometallurgical treatment of the waste polishing pastes. Carbon fibrous electrodes with gold and silver deposited on them are exposed to roasting in the flame of a burner; precious metals in the form of powder or bullion are recycled.

INTRODUCTION

Electrolytic plating of precious metals and their alloys in electrolytes with different compositions is used together with anodic etching of articles in sulfuric acid – thiourea solutions in jewellery production. In this process, precious metals should be extracted from waste electrolytes and washing solutions [1, 2]. Electrolysis is one of the reliable and promising ways of extracting metals from the stated solutions.

Processing of polishing pastes containing precious metals also presents a serious problem. For this purpose, an attractive approach is to use hydrometallurgical processes, as a result of which metals pass into solutions and are subsequently extracted electrolytically. At the stage of metal solution from pastes, it is desirable to use reagents which are currently in use in jewellery manufacturing.

Electrolysis enables one to obtain metals or metal alloys in compact form directly applicable to jewellery manufacturing; it does not involve additional reagents, and allows repeated use of solutions. Electrolysis offers a solution to environmental protection problems at an enterprise along with resource saving.

The present communication deals with investigation of the potentialities of electrolysis with carbon-graphite flow electrodes for solving the above problems of jewellery manufacturing.

GOLD AND SILVER EXTRACTION FROM SOLUTIONS RESULTING FROM ELECTROLYTIC ETCHING OF ARTICLES IN SULPHURIC ACID – THIOUREA SOLUTIONS

After smelting, gold jewellery is subject to anodic etching in sulphuric acid – thiourea solutions of the following initial composition: thiourea 80 g/l, sulphuric acid 98 g/l. The temperature of the solution is 25–30 °C. Electrolysis with carbon-graphite fibrous flow electrodes (CFEs) used for gold and silver extraction from sulphuric acid – thiourea eluates obtained by sorption technology of metal extraction from ores is reported in [3]. Peculiarities of sulphuric acid – thiourea solutions of electrolytic etching of jewellery are the higher contents of sulphuric acid, gold, and silver, thiourea content decreasing with time, and solution temperature increasing in the course of etching.

Jewellery articles are subjected to anodic etching in sulfuric acid – thiourea solutions; therefore, the content of thiourea (TU) gradually decreases due to its partial oxidation. Because of thiourea oxidation and binding in complexes with metal ions formed in the course of etching, the efficiency of the etching process gradually decreases. Prior to the removal of waste solutions from the process, precious metals should be extracted from them.

The washing solutions left after the etching and washing of articles contain gold and silver. The concentrations of gold, silver, and thiourea in real solutions can vary within wide ranges. For example, at the plant where the process was tested, the contents of the components varied from 6.9 to 0.62 g/l for gold, from 1.9 to 0.06 g/ l for silver, and from 80 to 20 g/ l for thiourea.

In this context, we performed studies to evaluate these effects on the efficiency of electrolysis and to select carbon fibrous materials (CFMs) that ensure high degree of extraction of precious metals from the specified solutions.

For these investigations, the circulation mode was used. A container with an etching solution (washing solution) was connected to the electrolytic cell. By means of a pump, the solution circulated between the container and the electrolytic cell, and the alloy of gold and silver deposited on the CFM cathodes [4].

It is known that electrolysis of sulphuric acid – thiourea solutions for eluting noble metals from ion-exchange resins provides higher rate of gold extraction compared to silver extraction because of the kinetic peculiarities of discharge for gold and silver [5, 6]. When both gold and silver compounds are present in sulphuric acid – thiourea solutions, the current regimes that ensure efficient extraction of silver enable gold extraction as well. The degree of gold extraction from a thiourea solution is higher when Au/Ag ≈ 10 (this ratio is common in anodic etching of jewellery of .585 gold hallmark). For example, when the initial content of Au and Ag in the solution was 256 and 27.5 mg/l, respectively, the degree of extraction for 1 h of electrolysis was (%): 98.5 for gold and 94.9 for silver.

As applied to electropolishing solutions, the effects of the metal and thiourea concentration, flow rate, and solution temperature on the efficiency of electroextraction of silver are best-studied cases. These parameters varied within the limits characteristic of real electropolishing solutions of jewellery articles.

The efficiency of gold and silver electroextraction was evaluated from current efficiency (E_c) and process productivity (W_β); the latter is defined as the volume of the processed solution per unit area of the electrode and unit time for the given degree of metal extraction [3]. Process productivity was calculated for $\beta = C_0/C_\tau = 50$ (C_0 and C_τ are metal concentrations in the solution before electrolysis and after a period of time τ, respectively), which corresponds to 98 % extraction of metal. Analysis of solutions for gold and silver contents was performed by the atomic absorption method. Silver electroextraction from thiourea solutions of anodic etching of jewellery was investigated with a VVP-66-95 type carbon fibrous material whose properties are described in [4].

Electrodeposition of silver from sulphuric acid – thiourea solutions is limited by diffusion of the discharged particles [5]. Therefore, when the solution temperature increases from 20 to 50 °C, the productivity of the process and its current efficiency by silver increase by a factor of ~1.7, reaching 52 $m^3/(m^2$ days) and 55 %, respectively. As the solution's flow rate increases by a factor of 10, the process productivity increases by a factor of 2.2–2.3.

When the thiourea concentration decreases from 80 to 10 g/l, the equilibrium potential of a silver electrode is shifted from −135 to +64 mV (relative to the standard hydrogen electrode) [7]. The difference between the equilibrium potentials of the silver and hydrogen electrodes ($\Delta E^{\mathrm{H}}_{\mathrm{Ag}}$) increases; therefore, according to current theoretical knowledge about the operation of carbon flow electrodes, the efficiency of metal electroextraction should increase, as supported by evidence presented in Fig. 1, *a*.

When the content of silver ions in the solution increases, the value of $\Delta E^{\mathrm{H}}_{\mathrm{Ag}}$ increases, while W_β decreases (see Fig. 1, *b*). This is caused by the macrokinetic peculiarities of CFE functioning. As is known, at higher concentrations of the deposited metal in

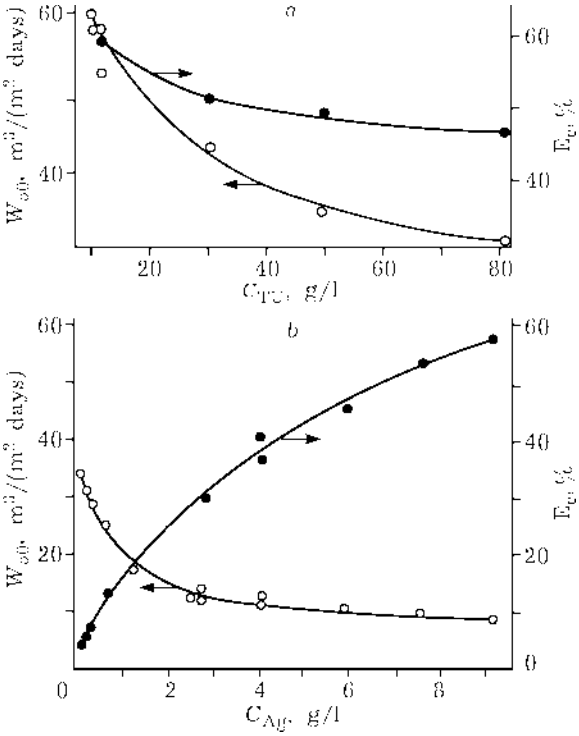

Fig. 1. Dependence of the productivity of silver electrodeposition (W_{50}) and current efficiency (E_c): *a* – on the concentration of thiourea C_{TU} in a solution containing (g/l): Ag 1.1, H_2SO_4 30; *b* – on the concentration of silver C_{Ag} in a solution containing (g/l): TU 30, H_2SO_4 30. Cathode current density is 1000 A/m^2.

solution the efficiency of CFE decreases due to process localization on the periphery of the electrode. The metal settles mainly at the inlet and outlet of the electrode, avoiding the middle [8]. The higher the thickness of the electrode, the greater the effect. Thus, for electroextraction of gold and silver from sulfuric acid – thiourea solutions of electrolytic etching of jewellery, electrodes not thicker than 2–4 mm should be used.

Solutions for testing the industrial conditions of electrolysis were obtained as a result of etching articles of .585 gold hallmark. The results obtained in a jewellery company and summarized in Table 1 suggest that gold and silver can be effectively extracted from etching and washing solutions by electrolysis with CFE. The degree of extraction from the specified solutions was 99.8–99.9 % for gold and 99.4–99.8 % for silver. The data listed in Table 1 were obtained on a setup with an overall electrode area of 60 cm^2 and an etching bath volume of ~5 l.

A carbon cathode with a gold-silver alloy deposited on it was subjected to roasting and melting. The gold content in a bullion was 80–90 %, and the total content of gold and silver was more than 99 %.

If gold and silver are continuously extracted from etching solutions (in the course of article etching), the residual concentration of these metals is maintained at a low level. This leads to steady operation of the etching bath and increases its service life. Changes in the ratio of gold and silver contents in sulphuric acid – thiourea solutions owing to etching of jewellery articles of varying gold contents has no pronounced effect on the process parameters of electrolytic extraction of gold and silver with CFE. Thus electrolytic extraction of gold and silver from sulphuric acid – thiourea solutions of jewellery etching may be used for extracting these metals from the etching solutions of gold articles of any hallmark.

EXTRACTION OF GOLD AND SILVER FROM WASHING SOLUTIONS AND FROM WASTE ELECTROLYTES OF METAL ELECTRODEPOSITION

The main electrolytic coatings of precious metals used in jewellery manufacturing are

TABLE 1

Extraction of gold and silver from sulphuric acid – thiourea solutions of gold jewellery etching

Solution	Electrolysis conditions			Concentration of metals*, mg/l	
	I, A	*U*, V	τ, h	Au	Ag
Etching solution	15–20	5.5	1.75	6900/20	1900/4
Washing water	5	7.0	0.5	620/1	60/0.1

*Numerator – initial metal content; denominator – final metal content.

coatings of gold, silver, and their alloys. Electrolytes of galvanic gold and silver plating are close (in major components) to electrolytes used for electroplating with precious metals in other industries [1, 2, 9]. Electrolytes used in jewellery manufacturing generally enable one to obtain gloss and semi-gloss coatings when special brighteners are introduced in the solution. After deposition, jewellery articles are washed in two or three nonflow baths, which gradually accumulate precious metals subject to extraction.

Earlier, it was shown that gold and silver may be electrolytically extracted from the washing solutions of gold and silver plating operations from some electrolytes [10]. The procedure of [10] was used for investigations which made it possible to recommend electrolytic extraction of gold and silver from a wide variety of electrolytes applied in jewellery manufacturing. Note that precious metals exist in the form of complexes in electrolytes. To assess the possibility of metal electrodeposition from the washing solution, the effects of the dilution factor of the supporting electrolyte on the conductivity, pH, and cathodic polarization characteristic have been studied. This study is necessitated by the fact that the concentration of the components of the supporting electrolyte will increase in the course of metal extraction from the washing solution, tending to the concentration in the metal deposition electrolyte. The ensuing changes in the conductivity and pH of the solution, as well as changes in the equilibrium (or steady-state) potential of the gold (or silver) electrodes, will affect the parameters of metal electrodeposition from the washing solutions [10].

Let us consider some results, which are of great significance in developing processes of precious metal extraction from washing solutions. The choice of electrolytes for gold and silver electrodeposition was dictated by the need to illustrate the basic tendencies governing precious metal extraction from washing solutions. Figure 2 shows the polarization curves recorded on the disk microelectrode refreshed inside the solution. Curve *1* defines oxygen reduction, curve *2* defines concurrent reduction of oxygen and metal, and curve *3* characterizes the same process with “free” cyanide ions present in the solution. On all three plots, the substantial rise on the polarization curve in the region after −1.0 V is due to the reduction of hydrogen ions and release of gaseous hydrogen. Similar dependences of gold and silver deposition were obtained for the majority of the solutions simulating washing solutions. Their analysis led us to conclude the following: 1) oxygen reduction starts at higher positive potentials, and hence metal reduction is preceded by oxygen reduction, which demands a significant amount of electricity; 2) metal extraction is maximum when current density increases to values corresponding to metal reduction with the limiting diffusion current; 3) further increase in current density does not affect metal extraction, but decreases current efficiency because the potential of intense evolution of gaseous hydrogen has been attained.

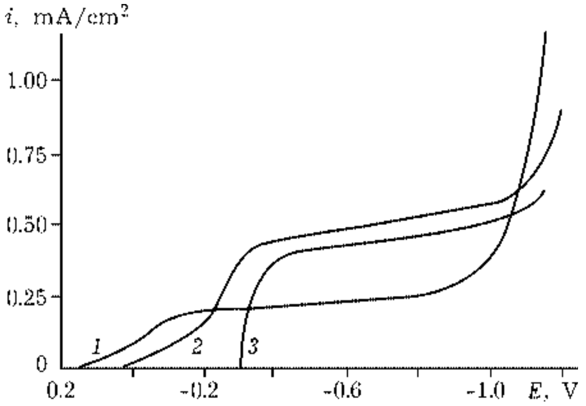

Fig. 2. Polarization curves for a cathodic process in a solution of the following composition (g/l) : *1* − K_2CO_3 25; *2* −K_2CO_3 25, $K[Ag(CN)_2]$ 0.25; *3*− K_2CO_3 25, $K[Ag(CN)_2]$ 0.25, KCN 1.0.

The effects of these processes on metal reduction are illustrated by the data presented in Fig. 3. At low current densities, current is mostly consumed for oxygen reduction. At increased current densities (to 5 mA/cm^2), the current consumed on metal extraction increases, and then (when current density is more than 5 mA/cm^2) hydrogen ion reduction starts to prevail, resulting in a drastically decreased current efficiency.

Dilution of the supporting electrolyte strongly affects the parameters of metal extraction. The dependences of the degree of metal extraction and current efficiency on the dilution factor of the solution usually exhibit a maximum (Fig. 4). These dependences are typical

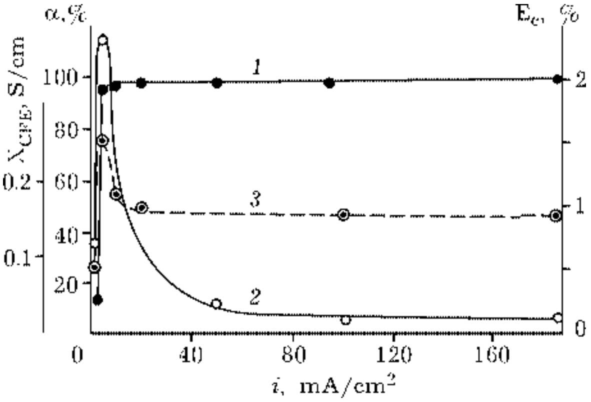

Fig. 3. Effect of current density (*i*) on the degree of electrolytic extraction of gold α (*1*), on the current efficiency of gold E_c (*2*), and on the conductivity of CFE with gold χ_{CFE} (*3*). The composition of the solution (g/l): Au 0.005, $C_3H_4OH\ (COOH)_3$ 1.0, KH_2PO_4 1.2, K_2HPO_4 3.0, $C_3H_4OH(COOK)_3$ 18.0.

for the majority of the studied electrolytes, and reasons for their extreme behavior are probably the following. On the one hand, as the concentration of the supporting electrolyte increases, the conductivity of solution is raised, and performance of the electrode is liable to improve; on the other hand, increased concentration of the complexing agent decreases the effective working thickness of the electrode and the metal extraction rate [8]. For highly diluted supporting electrolytes, the difference between the potential of metal deposition at limiting current and the potential of hydrogen evolution increases, and so does the resistance of the solution. Therefore, every electrolyte under study is characterized by a definite value of dilution, which ensures the best performance of the metal extraction process. For most electrolytes, this value depends on the properties of the solution and electrode and varies from 5 to 15. The individual properties of the solutions are most pronounced at small degrees of dilution.

The uniformity of metal distribution across the thickness of the electrode is an important feature controlling the process efficiency. Therefore, this characteristic was estimated along with the degree of extraction and current efficiency; this was done visually or by conductivity measurements for an electrode with metal. Interesting results were obtained for metal distribution throughout the electrode volume as a function of current density (see Figs. 3 and 5) and dilution of the supporting electrolyte (see Fig. 4). The greater the uniformity of metal distribution across the thickness of the electrode, the higher the conductivity. The greatest uniformity of metal deposition was achieved at current density of 50–100 mA/cm^2 (initial concentration of gold in the solution is 20 mg/l) and ~5 mA/cm^2 (initial concentration of gold is 5 mg/l). Increased current density results in deposition of the major portion of gold near the current lead; when current density decreases, the metal is redistributed to the frontal side of the electrode. Under conditions of the maximum degree of

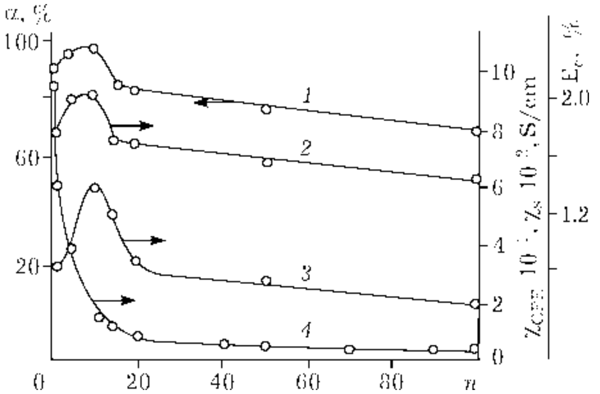

Fig. 4. Effect of the dilution factor (*n*) of the supporting electrolyte on the degree of extraction α (*1*), on the current efficiency of gold E_c (*2*), on the conductivity of CFE with gold χ_{CFE} (*3*), and on the solution conductivity χ_s (*4*). The composition of the supporting electrolyte (g/l): $C_3H_4OH(COOH)_3$ 10.0, KH_2PO_4 12.0, K_2HPO_4 30.0, $C_3H_4OH(COOK)_3$ 180.0.

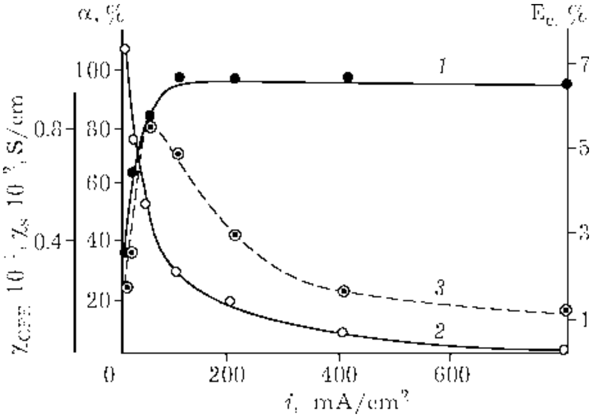

Fig. 5. Effect of current density (*i*) on the degree of gold extraction α (*1*), on the current efficiency of gold E_c (*2*), and on the conductivity of CFE with gold χ_{CFE} (*3*). The composition of the solution (g/l): Au 0.020, $C_3H_4OH(COOH)_3$ 1.0, KH_2PO_4 1.2, K_2HPO_4 3.0, $C_3H_4OH(COOK)_3$ 18.0.

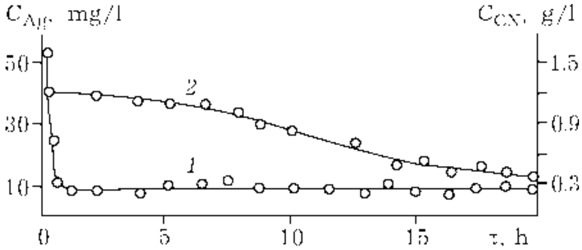

Fig. 6. Variation of the concentrations of silver C_{Ag} (*1*) and cyanide ions C_{CN} (*2*) due to article washing in the course of electrolysis. The composition of the silver plating electrolyte (g/l): $K[Ag(CN)_2]$ 30 (Ag), KCN 90, K_2CO_3 25, eldine 2; silver content increased to 40 mg/l after 30 min (one washing of articles); cathode current density 500 A/m^2.

extraction (100 mA/cm^2, initial concentration of gold is 20 mg/l), the metal is deposited as a uniform thin film repeating the configuration of the fibers. Increased current density and initial concentration of the metal causes gold deposition in the form of "islets" coalescing in the course of electrolysis.

The greatest uniformity of metal distribution across the thickness of the electrode is achieved when the dilution factor of the supporting electrolyte is $n \sim 10$ (see Fig. 4), which corresponds to the highest conductivity of CFE with metal. The conductivities of the solution and initial CFM are comparable in this case, which should correspond to the greatest uniformity of potential distribution across the thickness of the electrode. At low values of n, the metal deposits mainly on the rear side of the electrode; at high values of n, on the frontal one. The values of dilution factors at which uniform distribution is achieved are individual for electrolytes and depend on the properties of the CFM used.

The maximum quantity of the metal that can be deposited on the electrode under conditions of uniform deposition with a high degree of extraction is 25–30 g for gold and 15–20 g for silver per 1 g of CFE. The carbon-graphite cathodes saturated with precious metals are subjected to roasting to obtain powder or bullion, the carbon-graphite material being burnt out in the process.

The possibilities for solving ecological problems along with extraction of precious metals are illustrated by the data presented in Fig. 6. When jewellery articles are intermittently washed in a rinse tank, the whole amount of silver introduced during the process in the solution is extractable by electrolysis. The silver concentration is maintained at a constant low level (see Fig. 6, curve *1*). The concentration of the cyanide ions is also kept at a low level due to anodic oxidation (see Fig. 6, curve *2*). Oxidation of thiocyanide ions and hydrazine is accomplished in a similar way.

A variety of CFMs can be used for extracting precious metals from washing solutions, which is illustrated by the data of Table 2; the properties of CFMs are presented in [4, 8]. The results were obtained in a single pass of solution through the bulk of an electrode.

Extraction of gold and silver from waste electrolytes can be performed directly from electrolytes or after dilution. Gold was deposited from the washing solutions, from the cyanide, citrate-phosphate, and oxalic electrolytes of galvanic gold plating, and from electrolytes of chemical gold plating, namely, ammonium-carbonate electrolytes with hydrazine and electrolytes based on sodium hypophosphite.

TABLE 2

Effect of the type of CFM on gold extraction from the citrate-phosphate washing solution.
Cathode current density 100 mA/cm^2, electrode thickness 0.3 cm, solution flow rate 0.2 ml/(s cm^2)

CFM	Initial concentration, mg/l	Degree of extraction, %
Mtilon	21.25	97.9
KNM	20.4	89.6
VVP-66-95	20.4	87.3
NTM-100	20.5	87.0
VNG-30	20.3	60.1

Silver was deposited from solutions of galvanic silver plating: cyanide, thiocyanide, ferricyanide, and thiocyanide-cyanide solutions.

STUDYING THE POSSIBILITY FOR GOLD AND SILVER EXTRACTION FROM POLISHING PASTES BASED ON IRON AND CHROMIUM

Polishing pastes appreciably differ in their composition from gold and argentiferous ores. Gold in its ores, as a rule, occurs in a metal state, while silver is present preferentially in the form of compounds: Ag_2S, Ag_2Te, Ag_3SbS_3, Ag_3AsS_3. The pastes contain alloys of gold with silver and nonferrous metals, chrome and/or iron oxide, and also organic components: paraffin, stearine, and oleic acid, which can affect both leaching and electrolytic extraction of gold and silver.

Investigations of gold and silver solution in polishing pastes containing one or both of these elements were conducted on a model polishing paste, which was the ground initial paste with a 20–30 mg addition of gold and/or silver powder. Thiourea–sulphuric acid solutions (TU 16–25 g/l, H_2SO_4 8–12 g/l) were employed as a solvent. This choice of solvent was dictated by the fact that the solutions are used in etching of jewellery. As is known, gold and silver form complexes with TU that are stable in acid solutions; for complexes of gold $[Au(TU)_2]^+$ and silver $[Ag(TU)_3]^+$, pK is 22 and 13.6, respectively [13, 14]. Therefore, thiourea solutions were suggested for leaching out these metals from some types of ores. Air oxygen, iron (III) salts, hydrogen peroxide, and potassium bichromate are used as oxidants because they promote gold and silver oxidation but do not oxidize thiourea [14–16]. In the present work, air oxygen and a hydrogen peroxide solution were used as oxidizers.

Leaching of gold

The possibility of direct extraction of gold by leaching with acidic thiourea solutions (TU 16 g/l, H_2SO_4 8 g/l) in the presence of air oxygen has been examined. The dependence of the degree of gold extraction from the paste on the leaching conditions (Table 3) has been studied. From the evidence presented it follows that: 1) the increased number of steps and leaching time raise the degree of gold extraction; 2) reducing the ratio between the solid and liquid phases (S : L) and elevated temperature reduce the degree of gold extraction; 3) three-stage leaching at ambient temperature makes it possible to effectively extract gold from polishing pastes by direct leaching.

However, electrolysis of the obtained solutions showed that gold failed to deposit on the carbon fibrous cathode, and the carbon fibrous material was destroyed during electrolysis. The reason for CFM destruction was the presence of the organic components in the paste: paraffin, stearine, and oleic acid.

Therefore, the next stage of investigations was selection of reagents for removing organic components from the pastes by their oxidation or solution in organic solvents. The best results were obtained by using organic solvents. After

TABLE 3

Effect of leaching conditions on gold extraction from polishing pastes

No.	S : L	Leaching conditions			Degree of extraction, %
		Number of steps	Solution temperature, °C	Leaching time, h	
1	1 : 20	1	40	1	36
2	1 : 20	2	40	2	47
3	1 : 20	3	40	3	51
4	1 : 20	3	20	3	75
5	1 : 6	3	20	3	65
6	1 : 20	3	20	6.5	85

TABLE 4

Effect of conditions on silver leaching from the polishing paste. Leaching temperature 20 °C

No.	S : L	Conditions of leaching		Degree of extraction, %
		Number of steps	Time, h	
1	1 : 10	3	4.5	42.6
2	1 : 10	3	6.0	52.0
3	1 : 20	1	6.0	99.0*
4	1 : 10	1	6.0	79.0*

*0.3 % hydrogen peroxide solution added.

treatment in organic solvents and washings in alkali and in acid, gold was leached out with a thiourea solution, transferred to the solution, and electrolytically deposited on the carbon fibrous cathode. Gold is readily leached with a sulphuric acid – thiourea solution from a fat-free paste and deposits on the CFE. Three-stage leaching at 20 °C for 7 h at S : L = 20 leads to 85 % extraction of gold, which settles in the form of brown fine crystals on CFE.

Leaching-out of silver

Leaching of silver from the model pastes was carried out with regard to the above-mentioned results. Silver powder was added to the ground initial paste. The resulting mixture was treated with benzine to extract the organic components of the paste, and then washed with an alkali and an acid. The results of silver leaching with sulphuric acid – thiourea solutions (TU 16 g/l, H_2SO_4 8 g/l) are presented in Table 4. It is evident that, as one would expect, in the presence of air oxygen, silver is extracted at a lower rate than gold. The addition of hydrogen peroxide as an oxidizer allows the degree of silver extraction to be raised considerably. The degree of silver extraction is 99.0 % even in the case of single-stage leaching.

Leaching gold and silver from pastes containing both elements

When 2 % gold and 2 % silver are present in a paste, two-stage leaching with a sulphuric acid – thiourea solution (TU 25 g/l, H_2SO_4 12 g/l) in the presence of hydrogen peroxide at S : L = 10 for 12 h at ambient temperature results in extraction of 75 % gold and 44.5 % silver.

Leaching gold and silver from the polishing paste waste of jewellery manufacturing

The waste of the polishing paste was a mixture of scraps of rag, cotton wool, brushes, and paste powder. Lumps of cotton wool, brushes, and rag were separated from the powder with a sieve. In the sieved out powder, the gold content was 2.35 %, and the silver content was 2.1 %. After the paste powder had been degreased with benzine and washed with an alkali and an acid, gold and silver were leached out with a sulphuric acid – thiourea solution (TU 25 g/l, H_2SO_4 12 g/l) in the presence of hydrogen peroxide (S : L = 10) at ambient temperature. Gold and silver were extracted from the leaching sulfuric acid-thiourea solutions by electrolysis on carbon fibrous electrodes. The degree of gold and silver extraction into the solution after five-step leaching was 96 and 99 %, respectively; after subsequent electrodeposition, it exceeded 99 %. The carbon cathodes with the deposited metals were roasted in the flame of a burner; the carbon fibrous material burned out to give a powder of gold and silver alloy, in which the net content of precious metals was over 99 %. After precious metals have been extracted, the sulphuric acid – thiourea solutions can be recycled to the leaching process.

High-performance electrolytic cells and apparatuses on their basis [17] are used to electrolytically extract gold and silver from the solutions considered in this contribution.

CONCLUSIONS

Thus it has been shown that gold and silver may be effectively extracted by electrolysis with cathodes of CFM from solutions formed at different stages of jewellery manufacturing: from electropolishing of stock material to finishing operations of electrolytic plating from various electrolytes. The waste polishing pastes may be processed by dissolving gold, silver, and their alloys in sulphuric acid – thiourea solutions with subsequent electrolytic extraction of metals on the cathodes of CFM. Gold and silver recovered from the solutions are recycled in the form of a high-standard powder or bullion after roasting or melting the cathode with the deposited metals. Apart from precious metals recovery, electrolysis with CFE makes it possible to solve the ecological problems of jewellery manufacturing by reducing the volume of waste solutions due to their recycling and by neutralization of washing waters from cyanides, thiocyanides, and other toxic components by means of their anodic oxidation.

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