

# Improvement of Technology of Processing of Persistent Gold-Bearing Ores and Concentrates using Oxidative Burning



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*The article considers issues of improvement of the technology of processing of persistent gold-bearing ores and concentrates. The initial raw material is proposed to be subjected to oxidative roasting before cyanation. This is due to the fact that in persistent ores gold is found in such minerals as pyrite, chalcopyrite, arsenopyrite, etc. In turn, these minerals are surrounded by a layer of coal, which significantly reduces the efficiency of gold cyanation. Under oxidative firing conditions, coal is proven to burn by oxygen blowing, and minerals are decomposed into constituent components. In addition, under high temperature conditions, mineral grains are decripted due to their uneven chemical expansion. At the same time, numerous pores and cracks appear in the solid body, through which cyanides penetrate to gold minerals. All this creates good conditions for intensification of the process of extraction of noble minerals from the raw materials.*

**Keywords:** persistent gold-bearing ores, concentrates, oxidative roasting, pyrite, chalcopyrite, arsenopyrite, coal, processing efficiency, decomposition of minerals, thermal decription.

## I. INTRODUCTION

In the main directions of economic development of Uzbekistan for 2017-2021 it is noted that the main task of modern scientific and technological progress of Uzbekistan at the present stage is to increase the pace and efficiency of economic development on the basis of acceleration of scientific and technological progress, technical re-equipment and reconstruction of production, intensive use of the created production potential, improvement of the management system, economic mechanism and achievement, on this basis, of further improvement of well-being of the people [1].

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The aim is also to persevere in the rational and economic consumption of all types of resources, reduce their losses, accelerate the transition to resource-saving and waste-free technologies, and significantly improve the use of secondary resources and waste production. One of the decisive directions of implementation of the assigned tasks in non-ferrous metallurgy is creation and wide application of technical means and technologies for rational complex use of ore deposits, involvement in economic turnover of intermediate products and wastes of production, increase of volume of collection and processing of secondary metal raw materials [2].

Over the past decades, the share of gold extracted from technically simple gold ores, which can be successfully processed according to standard schemes, has been steadily decreasing. At the same time, the proportion of gold extracted from such ores, the efficient processing of which requires much more complex and developed schemes, including the operation of gravitational enrichment, flotation, burning, melting, leaching, etc., increases [3].

At present, coal ore is involved in industrial production at Navoi Mining and Metallurgical Plant. Gold in such ores is contained in various sulfide minerals, and the minerals themselves are covered with a carbonaceous layer. The difficulty of processing such ores is that the coal shields direct contact of the gold with the solvent and, furthermore, the leached metal is sorbed by the carbonaceous material and the yield is significantly reduced. [4]

The most effective method of extracting gold from carbonaceous ores is oxidative roasting at moderate temperatures.

## II. OBJECT AND METHOD EXPERIMENTS

The Department of Metallurgy of Tashkent State Technical University carried out research on processing of persistent gold-bearing carbon ores.

Carbonaceous gold-bearing ores are relatively rare in nature. They account for no more than 2% of all world gold reserves. But for the gold-bearing ores of Uzbekistan this problem is very urgent.

The main reason for the persistence of the carbonaceous (graphite) gold-bearing ores in the cyanide solution is the distinct precipitation capacity of the coals with respect to the dissolved gold and silver. If carbonaceous substances are present in the initial ore, the latter can sorb noble metals from cyanide solutions, thereby increasing losses of gold and silver with tails of the enrichment process [5].

Many researchers have studied the causes of gold deposition from cyanide solutions by carbon-containing components [6 - 9].

Now the hypothesis that sedimentation of gold on coals happens in a consequence of adsorption of complex  $\text{Au}(\text{CN})_2^-$  anion is widespread. This assumption is supported by the fact that the amount of gold deposited is directly dependent on the total surface of the carbonaceous matter particles. It has been found that the speed and completeness of the transition of gold and silver to coal decreases with increasing temperature, which also indicates the adsorption nature of the deposition process [10, 11].

Depending on the nature of the feedstock, the methods of treating gold-bearing carbonaceous ores can be divided into the following main groups:

1) Direct cyanation of ore or concentrate in compliance with a special treatment regime, which eliminates the possibility of sorption of noble metals from solutions by ore components;

2) Cyanation in the presence of passivating reagents (kerosene, turpentine, flotation oil, etc.) which coat the surface of the carbonaceous particles to prevent further contact of these particles with the dissolved gold cyanide complex;

3) Pre-recovery of gold sorbed with carbonaceous minerals by treating ore or concentrate cyanation tails with appropriate desorbents (cyanides, sulfur or caustic alkali, etc.);

4) Recovery of active carbon from ore prior to cyanation by flotation enrichment or oxidative calcination;

5) Replacement of cyanide with other effective gold solvents, the use of which minimizes the possibility of sorption of metal from solutions by ore components.

In order to find out the processability of these processes, we carried out trial experiments on processing carbohydrate gold-bearing ores by the above-mentioned methods.

Direct cyanation of carbohydrate ores has shown that it is almost impossible to process these raw materials with acceptable technical and ecological indicators. In the cake, from 20 to 50% of gold remained from cyanation of its content in the initial ore.

The method of neutralizing carbonaceous substances in the cyanization of gold-bearing ores by exposing them to water-insoluble mineral liquids (flotation oils, kerosene, etc.) is related to additional costs for materials. In addition, kerosene and other minerals evaporate irretrievably losing a large amount of it and the ecology is disrupted. All this leads to higher production costs and reduced competitiveness of technologies.

Under practical mill conditions, a suitable way to desorb gold from cyanide tails is by thoroughly washing the cake with disinfected or fresh cyanide solutions, as well as using multiple pulp filtration with intermediate cake pulping. Anhydrous ammonia is a good desorbent of noble metals deposited on coals, but its use for washing gold and silver from cyanation tails cannot be recommended for economic and environmental reasons.

Of much greater practical interest is the possibility of using sulphurous alkalis, in particular sodium sulfide  $\text{Na}_2\text{S}$ . However, this technology also involves additional costs and reduced competitiveness.

The possibility of flotation extraction of graphite is based on the natural hydrophobicity of the mineral, which is markedly enhanced by the introduction of kerosene or other

similar reagents into the pulp. However, the recovery of graphite into the concentrate is not high. A significant portion of the carbon remains in the tailings of the flotation, deteriorating the conditions for subsequent cyanation of the ore.

### III. EXPERIMENTS AND RESULTS

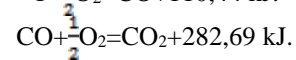
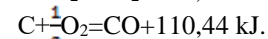
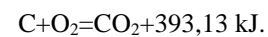
In our opinion, the following types of thermal treatment of ore raw materials can be used by the most promising method of passivating the carbonaceous substance in gold-bearing ores and concentrate subjected to cyanation:

1) Calcining the ore material in an inert gas atmosphere or under vacuum to remove the sorption active carbon monoxide as well as reduce the internal pores of part of the coal by recrystallization;

2) burning the carbon by oxidizing air with oxygen at elevated temperatures.

The former method is unlikely to be practical because of the great technological difficulties and the considerable cost involved. More promising is oxidative roasting of carbon ores and concentrates based on carbon removal into the gas phase.

In  $\text{C-O}_2$ , the following solutions are possible under standard conditions [12]:



With increasing temperature with excess carbon and lack of oxygen, carbon monoxide is more likely to form than its dioxide. Since carbon dioxide is a very strong oxide and carbon will be a very effective reducing agent.

In the next series of experiments, studies were conducted to determine the effect of burning gold-bearing ores and concentrates on gold recovery. It was assumed that carbon would be removed from the ore by its oxidation by reaction:  $\text{C} + \text{O}_2 = \text{CO}_2$ .

This reaction is accompanied by a significant thermal effect, which in some cases allows the firing process to be carried out without additional external fuel. As a result of this reaction, there will be a significant decrease in the sorption activity of the ore components with respect to dissolved gold and silver.

In the first series of experiments, we investigated the degree of carbon burning over time at different temperatures. In carrying out the works we used complex methods of research, including scientific and theoretical generalizations of theory and practice of processing gold-bearing ores. Graphoanalytic and static methods of analysis of results were used, in addition, spectral and mineralogical analysis, test tube, phase and chemical methods of research were used. The results of the studies are presented in Fig. 1. and Tab.1.

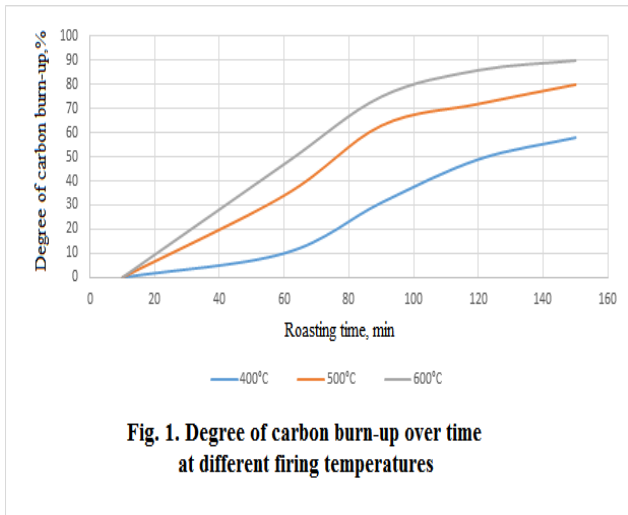


Fig. 1. Degree of carbon burn-up over time at different firing temperatures

Table 1. Degree of carbon burn-up over time at different firing temperatures

#	Rasting time, min	Degree of carbon burn-up, %		
		400°C	500°C	600°C
1	0	0	0	0
2	10	0	0	0
3	20	2	8,5	10
4	30	4	15	21,5
5	40	5	20	27
6	50	7,5	24	38
7	60	10	33,5	46
8	70	15	43	54,5
9	80	23	52,5	66
10	90	30	64	74
11	100	37,5	66	80
12	120	50	71,5	85
13	140	54,5	77	89
14	160	60	80,5	90,5

Degree of carbon burn-up is determined from initial and final concentration of carbon in solid product.

The decrease in the degree of carbon burn-up above 500 °C is due to the fact that pyrite, chalcopyrite and arsenopyrite are contained in the ore in sufficiently large amounts.

The ignition temperature of sulfides, size 0,075 - 0, 10 mm are: chalcopyrite - 357 °C; Pyrite - 405 °C; Pyrrotine 444 °C. At these temperatures, the sulfides ignite and the temperature in the solid is significantly increased. As a result, low-melting eutectic are formed in the volume of ore, some of the materials are melted and the process of carbon burning is stopped.

This was also facilitated by the fact that the experiments were carried out in a muffle furnace in the temperature range 400-600 °C. Boats and hangings were stirred every 5 minutes. However, in our view, the process took place in diffusion mode and the rate of carbon burnout was small.

In the second series of experiments, we investigated the degree of gold extraction in the cyanation of the ogark.

Initial concentration of gold in a candle end made 93g/t.

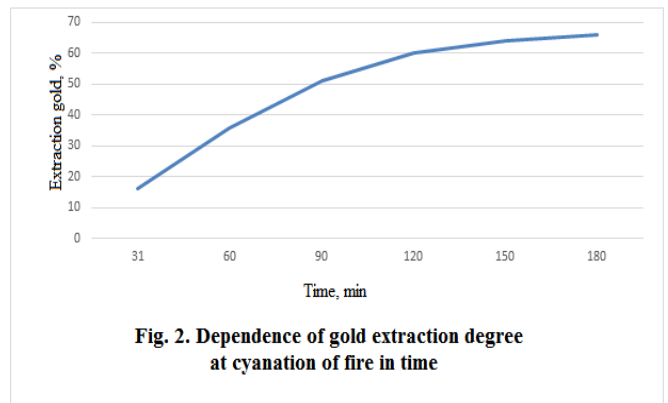


Fig. 2. Dependence of gold extraction degree at cyanation of fire in time

Experiments were carried out at an oven temperature of 550-600 °C. It can be seen from Figure 2 that the degree of gold recovery increases to a firing time of 120 to 150 minutes. Further holding does not lead to improvement of indicators. During this time, it appears that the surface of the calcined material is coated with a film of oxides and direct contact of the oxidizable material with the oxidant is stopped. The process goes into diffusion mode, and the diffusion coefficient of substances at these temperatures is very small.

The technological and technical-economic indices of the process of extraction of noble metals from carts are influenced by the ratio of solid and liquid in the pulp. Figure 3 shows the results of these studies. The experiment was carried out under the following conditions: firing temperature 550 - 600 °C, firing time 150 minutes.

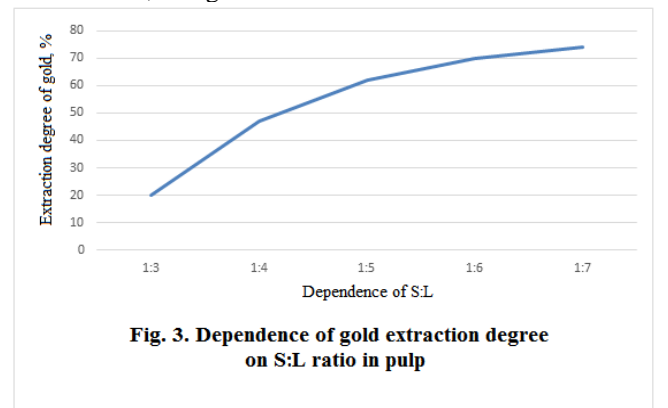


Fig. 3. Dependence of gold extraction degree on S:L ratio in pulp

The data in Figure 3 show that the gold recovery rate increases to a S:L ratio of 1:5/1:6. Further increase of its indicators does not give significant increase.

#### IV. CONCLUSION

Our studies have shown that when fired under standard conditions in a muffle furnace, the results are not satisfactory when the carbonaceous matter is removed from the ore. Periodic mixing of ore in the boat does not fundamentally change the picture. Under these conditions, some carbon remains in the cucumbers, which adversely affects gold recovery during cyanation. The overheating of the charge impairs the conditions of mechanical opening of gold-containing sulfides, which also leads to additional losses of metal with tails. In our view, good results can be obtained by burning in a fluidized bed. In this case, the cucumbers will be obtained in porous form.

Reactions will proceed in kinetic mode. Materials will not stick due to fusion, as excess heat will be carried away by the rising gas-air flow. At the same time, the firing time can be reduced to 60 - 80 minutes, which allows to almost double the efficiency of the burning process.

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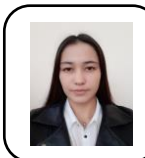
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