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# OPTIMISATION OF ROASTING OF ARSENIC-CARBON REFRACTORY GOLD ORES FOR CYANIDE LEACHING

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To optimize the technology for Bakyrchik deposit gold ore processing according to roasting - cyanidation pattern, the researches on sorption properties and the influence of carbon-bearing minerals content in calcine on gold recovery have been carried out. The results of conducted investigations showed that sorption properties of coal - Au concentrate during roasting process change even at relatively high residual carbon content in the calcine. Chemical sorption, dominating in gold-bearing solutions contact with coal concentrate, changes into physical sorption after its roasting. Roasting was applied in order to liberate noble metals, to produce the calcine with porous structure, unaffected by processes of surface melting and sintering.

*key words: carbon-bearing minerals, sorption, gold recovery, roasting-cyanidation process, carbon in pulp, arsenic-carbon gold-bearing ores*

## INTRODUCTION

Bakyrchik deposit located in East Kazakhstan is one of the largest in the world gold ore deposits (Komarov, Tomson 2007; Yakubchuk 2004). Difficulties in processing of Bakyrchik ores are caused by extremely fine dissemination of gold in arsenopyrite and pyrite and by the presence of active carbon agent having high sorption capacity with respect to gold-cyanide complex.

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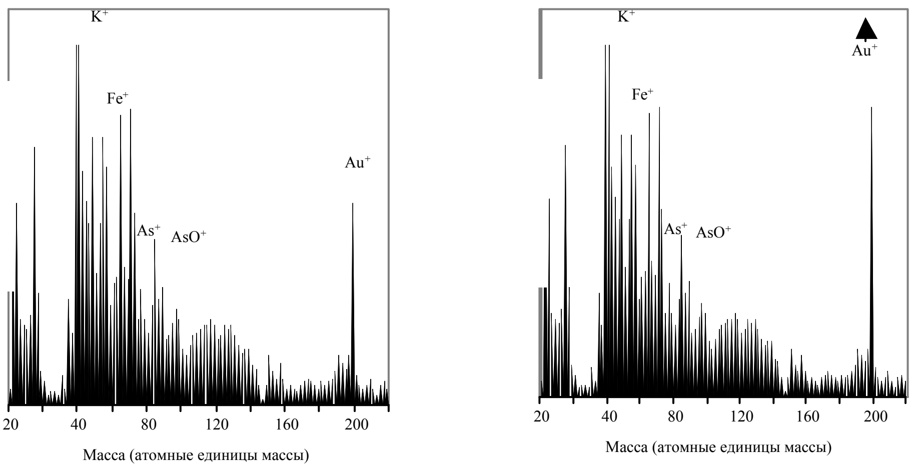
Decomposition of iron sulphides (arsenopyrite and pyrite) can be effectively carried out using either pressure and bacterial leaching or different types of roasting. However, in most cases it does not always provide high gold recovery in the following cyanide leaching of solid residues or calcines because of high content of sorption-active (pregg - robbing) carbon agent (Fridman, Savari 1985; Ibrado, Fuerstenau 1992: Sobel et al. 1995; Lodeischikov 1999; Tretbar 2004, Lars et al. 2007). Carbon removal at the step of enrichment is usually connected with considerable decrease in gold recovery (from 88–90 to 70%).

The highest gold recovery was observed during pilot plant tests to process Bakyrchik gold-bearing concentrates. Bacterial leaching (with recovery of 68–80%) and oxidizing roasting (with recovery of 78–84%) were used in the tests.

Gold recovery might be increased without gold losses at the enrichment step. To process finely ground ore directly, the use of oxidizing roasting process might be recommended as an alternative.

## EXPERIMENTAL

Laboratory investigations for development of roasting technology for carbon, arsenic and sulfur removal, were initially carried out in Kazakhstan (VNIItsvetmet). Subsequently, pilot plant tests were performed by “FFE Minerals” company (USA) using Waelz kiln with the length of 4.5 m and the diameter of 0.3 m (Trancoso et al., 2006).




a) b)

Fig. 1. Surface spectrum of calcine carbon agent (a) and calcine leaching residue (b).

In the course of pilot tests, the process parameters were changed, in which there was the variation of material retention time in the kiln (1–4 hours), ore grain size (1, 2, 5 mm), temperature (650–790°C), oxygen partial pressure in different areas of the kiln, carbon residual content in calcine was from 0.2 to 0.99%.

It was found that carbon - bearing agent, not removed during roasting, was impregnated into quartz. Subsequent grinding of calcine before leaching exposed the surface of carbon agent. Consequently, the calcined material sorbed gold from cyanide solutions. To determine gold concentration directly on carbon agent particles the method of TOF-RIMS was used. Figure 1 exhibits the results of analysis.

From data presented in Figure 1 it can be found that gold concentration in surface layer (thickness – 7 nm) of calcine carbon agent was 14.8 ppm before cyanide leaching and increased to 100 ppm – after gold leaching. Examinations of cyanide leaching of calcines indicated that decrease in carbon content in calcine not always results in increase of gold recovery into the cyanide solution.

## RESULTS AND DISCUSSION

To determine the effect of carbon content in calcine on gold recovery in leaching and for technology parameters optimization, the series of experiments were carried out. Experiments on differential thermal analysis (TGA/DTA) of ore samples and ore coal concentrate were conducted on thermoanalyzer "Rigaku Denki" in air atmosphere with heating rate of 20 °C/min (Figure 2, 3). Maximum heating temperature was 1000 °C.

Temperature interval, accompanied by DTA effect, was 430 – 770 °C. In the established temperature interval DTA has two maximum exothermic effects overlaid on each other at 496 and 615 °C. Loss of a portion of weight was found to be 7.4 %. It is supposed that heat release is connected with oxidation of pyrite and arsenopyrite sulfur in a sample. The second significant exothermic effect begins at the temperature of 550 °C and continues up to approximately 800 °C. This second peak is probably appearing as a result of carbon oxidation.

Temperature range, accompanied by DTA effect, while analyzing coal concentrate is 430–830°C. In the examined temperature interval there is one big exothermic effect detected with the maximum at 540°C. Loss of portion weight was determined to be 21.0%.

Therefore, TGA/DTA data show that for complete carbon burning-out from the ore the rise of ore roasting temperature is necessary. It was found, that maximum porous calcines were formed at temperatures 600–700°C. Taking into account that during roasting phase changes of carbon precede its burning-out and different carbon modifications possess markedly various sorption properties. There were conducted examinations of gold sorption using unroasted and roasted coal flotation concentrate of Bakyrchik ore. Chemical analysis results of examined samples are presented in the Tab. 1.

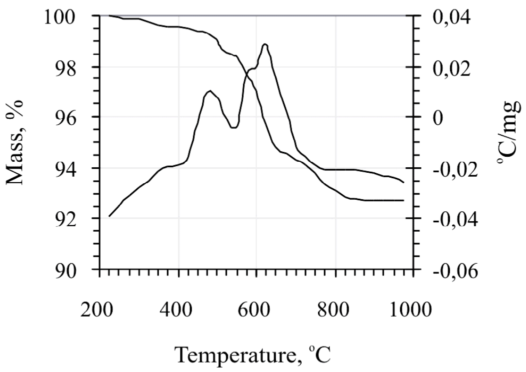


Fig. 2. TGA/DTA analysis of gold-bearing ore.

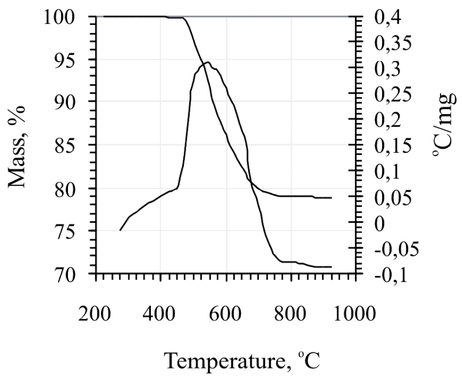


Fig. 3. TGA/DTA analysis of coal concentrate of gold-bearing ore enrichment.

Table 1. Chemical analyses of gold-bearing coal concentrate.

| Sample | Content | | | | | |
|---|---|---|---|---|---|---|
| | Au, g/Mg | As, % | Fe, % | S, % | C, % | Ca, % |
| Coal concentrate, raw | 42.3 | 4.30 | 10.5 | 7.87 | 14.70 | 1.10 |
| Coal concentrate, calcine (650 °C, 3.5 hours) | 58.0 | 1.26 | 12.3 | 0.92 | 2.05 | 1.35 |

Sorption capacity and samples sorption isotherms at different temperatures were determined using artificially prepared gold-cyanide solutions (20–150 mg/dm$^3$ Au, 0.03 % NaCN). Samples of coal concentrate and coal concentrate calcine were agitated in closed bottles for 24 hours in gold-cyanide solutions of different gold concentration.

After analysis of both solutions and solid products on gold content in experiments with coal concentrate sorption isotherms were determined (Figure 4). Moreover, the process activation energy was calculated to be 124 kJ/mole. Coal concentrate sorption capacity increased with the rise of temperature and at the temperature of 75 °C it achieved 2380 g/Mg.

The experiments performed with calcine coal concentrate showed that concentrate calcine contact with gold-bearing solutions resulted in decrease of gold content in solids from 58 g/Mg (initial content) up to 45–11 g/Mg and practically was not dependent on gold initial concentration in solutions (10–150 mg/dm$^3$). At temperature rise the content of gold in solid products was reduced (Figure 5). It was connected with the decrease of their sorption capacity and the increase of leaching rate, that evidently took place in spite of cyanide low concentration (0.03 %). Calculated activation energy of the process amounted to 47 kJ/mole.

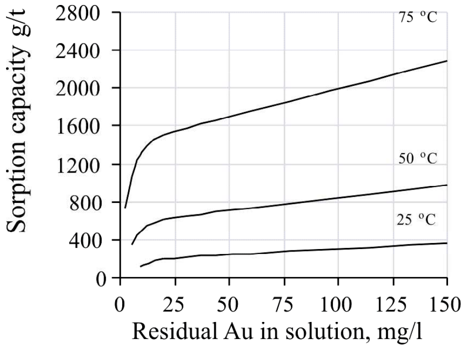



Fig. 4. Isothermal curves of gold sorption using coal concentrate.

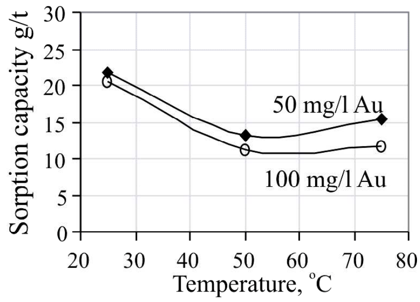



Fig. 5. Temperature dependence of coal concentrate sorption capacity.

## CONCLUSIONS

The results of conducted investigations showed that sorption properties of coal - Au concentrate during roasting process change even at relatively high residual carbon content in the calcine. Chemical sorption, dominating in gold-bearing solutions contact with coal concentrate, changes into physical sorption after its roasting. As far as physical sorption, in contrast to chemical sorption, is a reversible process, in order to reduce gold sorption property on calcine carbon agent, the consumption of absorbent coal into cyanidation pulp might be increased, that was confirmed by pilot test processing results.

Roasting was applied to provide maximum liberation of noble metals, production of calcine with porous structure, unaffected by processes of surface melting and sintering. Optimum burning - out ratio of carbon for every batch of ore shall be determined by results of calcine testing on gold recovery in the process of cyanide leaching by “coal in pulp” technology.

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**Kushakova L., Muszer A.,** *Optymalizacja przeróbki złotonośnych rud arsenowo-węglowych na drodze prażenia i cyjankowania.* Physicochemical Problems of Mineral Processing, 43 (2009), 59–64 (w jęz. ang)

Złoże Bakyrchik, leżące we Wschodnim Kazachstanie, jest jednym z największych złóż złotonośnych w świecie. Ruda złota charakteryzuje się występowaniem bardzo drobno rozproszonego złota w arsenopirycie i pirycie wraz z substancją węglistą, posiadającą wysoką zdolność sorpcyjną w odniesieniu do kompleksów cyjankowych złota. Głównym celem badań było określenie możliwości pozbycia się z rudy substancji nieużytecznych, tj. węgla oraz związków arsenu w celu uwolnienia złota, a następnie jego wyługowania. Przeprowadzone badania DTA wykazały, że najkorzystniejszy ubytek masy w trakcie prażenia materiału poddanego eksperymentom zachodzi przy temperaturze 540$^{o}$C (najlepszy efekt egzotermiczny). Po analizie roztworów i produktów stałych w eksperymentach z węglowym koncentratem wykreślono izotermy sorpcji i obliczono energię aktywacji procesu, która wynosi 124 kJ/mol. Sorpcyjna pojemność analizowanego węglowego koncentratu powiększała się wraz ze wzrostem temperatury procesu i osiągnęła 2380 g/Mg w temperaturze 75$^{o}$C. Rezultaty przeprowadzonych badań pokazały, że sorpcyjne właściwości rudy złotonośnej, zawierającej znaczne ilości substancji węglistej, zmieniają się w trakcie procesu jej wypalania. Chemiczna sorpcja przeważająca w procesie eksperymentu, po wypaleniu rudy zmienia się na fizyczną. Ponieważ fizyczna sorpcja, w odróżnieniu od chemicznej, jest procesem odwracalnym, można obniżyć sorpcyjność złota na węglowej substancji powiększając aktywność węgla w procesie cyjankowania. Prażenie rudy złota powinno spowodować jak najlepsze uwolnienie metali szlachetnych, powstanie porowatej struktury, nie zniszczonej w wyniku topienia i spiekania. Optymalny stopień wypalenia węgla dla każdej partii rudy powinien być poprzedzony eksperymentami, których celem musi być maksymalne odzyskanie złota w procesie ługowania cyjankowego “coal in pulp”.

*słowa kluczowe: rudy Au trudnowzbogacalne, rudy złota, arsenki Au-nośne, sorpcja, złoto drobnodyspersyjne, procesy cyjanowania, złoże Bakyrchik,*