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Effect of Two-Stage Roasting Conditions of Arsenic Containing Gold Concentrate on Cyanide Extraction Rate of Gold

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Abstract **Original Research Article**

The effects of roasting temperature and excess-air coefficient on dearsenization rate and gold extraction rate was investigated in two-stage roasting process of arsenic containing gold concentrate.
The result shows that roasting temperature and excess-air coefficient are main factors influenced on dearsenization rate and gold extraction rate. In first stage roasting process the roasting temperature and excess-air coefficient have significant effects on dearsenization rate. If the first stage roasting temperature is above 550℃ and the excess-air coefficient is higher than 0.85, the dearsenization rate is decreased and it causes decrease of gold extraction rate. In second stage roasting process the roasting temperature influences on specific surface area of calcine and gold extraction rate increases with increment of specific surface area. The second stage roasting temperature above 650℃ causes decreasing of the specific area of calcine and gold extraction rate.
In the second stage roasting process the gold extraction rate increases with increment of excess-air coefficient. But the excess-air coefficient more than 1.1 has negligible effect on gold extraction rate.

Keywords: Arsenic containing gold concentrate, two-stage roasting, roasting temperature, excess-air coefficient.

1. INTRODUCTION

The arsenic containing gold concentrate is known as refractory concentrate and the direct cyanide extraction rate of gold is very low. It is because the gold particles size in concentrate is very fine and encapsulated in sulfides such as pyrite and arsenopyrite. So the exposure of gold particles by only mechanical method is very difficult.

The oxidative roasting, bio-oxidation and autoclave oxidation are commonly used for pretreatment of refractory gold concentrate (Li., 2003; Yang et al., 2013; Li et al., 2014). The method of autoclave oxidation for this purpose has certain advantages in production cost and environmental protection, but it needs huge investment in equipment (Xu, B, et al., 2010). Bio-oxidation is another choice in view of low cost and environmentally friendliness. However, it is inefficient and too sensitive to environment (Wang Yun, et al., 2002).

Compared with these methods, the oxidative roasting operation is brief and productivity is high. In two-stage roasting, the sulfides such as pyrite and arsenopyrite are oxidized to reduce consumption of the cyanide and dissolved oxygen and the porous roasted material is produced to increase the gold extraction rate.

Two-stage roasting process is widely used for pretreatment of arsenic containing gold concentrate.

The first stage is done at weakly oxidative atmosphere to oxidize arsenic as As_2O_3 in the gaseous phase. The second stage roasting is carried out at oxidative atmosphere to produce porous Fe_2O_3.

Many investigations to increase gold extraction rate by oxidative roasting of arsenic containing gold concentrate have been studying.

Wang Jing et al. studied on two-stage roasting-cyanide leaching of arsenic containing gold concentrate with 43.99g/t Au and 2.04% As. They found that the optimal first stage roasting temperature is 500℃ and second stage roasting temperature is 650℃. And the gold extraction rate is 91.4% (Wang Jing, et al., 2013, Yuan Chao xin, et al., 2006).

Li Yun et al. indicated that the gold extraction rate is 94.96% from high arsenic-copper containing gold concentrate by weak oxidizing atmosphere roasting at 600℃ (Li Yun, et al., 2008).

R. R. Fernandez et al. investigated the effects of temperature on specific surface area of roasted material in roasting of arsenic containing gold concentrate and indicated that higher temperature and increasement of the arsenic amount results the decrease of specific surface area of the roasted material and reduced gold extraction (R. R. Fernandez et al., 2010)

In this paper the effects of roasting temperature and excess-air coefficient on gold extraction rate in two-stage roasting-cyanide leaching process of arsenic containing gold concentrate was investigated.

2. METHODS

2.1. Raw Materials

Chemical composition of the arsenic containing gold concentrate used in the present work was given in **Table 1**.

Table 1. Chemical composition of the arsenic containing gold concentrate (mass %)

Component	Au(g/t)	Ag(g/t)	Pb	Cu	Fe	S	As	SiO_2	CaO	C
wt%	16.7	86.8	0.95	0.13	27.5	27.37	3.28	24.8	6.2	0.83

As shown in **Table 1**, the content of S, As was high with 27.37%, 3.28%.

X-ray diffraction analysis (XRD; PW3040/60; PANalytical Corp., Almelo, the Netherlands) of the arsenic containing gold concentrate was also showed in **Figure 1**.

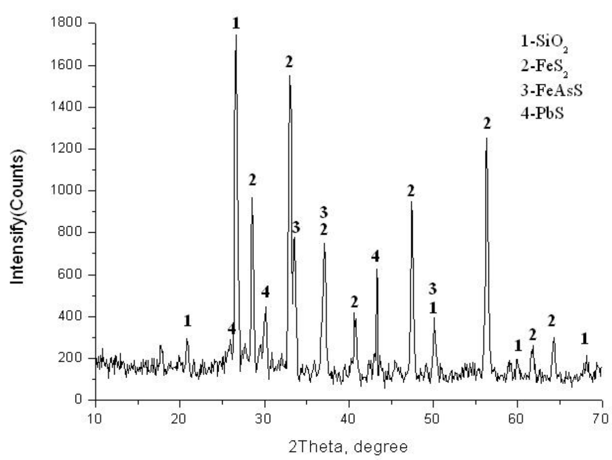


Figure 1. X-ray diffraction analysis of arsenic containing gold concentrate

As shown in **Figure 1**, the metal minerals are pyrite, arsenopyrite and galena. The gangue is silicate.

The distribution of grain size was shown in **Table 2**.

Table 2. The distribution of grain size

size, mm	content, %
-0.038	38.39
+0.038~0.048	9.02
+0.048~-0.074	23.99
+0.074~-0.15	16.36
+0.15	12.24
sum	100

2.2. Experimental apparatus and method

2.2.1. Experimental apparatus

Tube-type electrical furnace, blower, flow meter, ceramics container, thermostatic magnetic agitator (DF-101S), vacuum filter, JJ-1 type electric agitator, roller mill, balance.

2.2.2 Reagent

H_2SO_4 (98%), NaCN(45%), NaOH(90%), CaO(75%)

2.2.3 Experimental method

The experimental setup for two-stage roasting of arsenic containing gold concentrate is shown **Figure 2**.

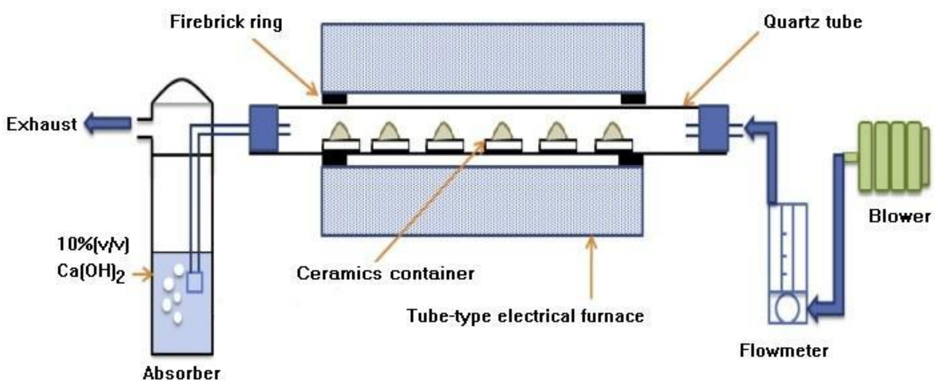


Figure 2. Schematic roasting experiment setup

The tube-type electric furnace is connected to blower and flow meter to feed the air from blower to electric furnace.

The concentrate sample is put on the ceramics container and is fed into tube-type electric furnace heated to first stage roasting temperature. And the air is supplied by valve of flow meter according to the first stage excess-air coefficient and the roasting time is 1.5h.

Then the temperature of tube-type electric furnace is raised to second stage roasting temperature and the air is supplied by valve of flow meter according to the second stage excess-air coefficient and the roasting time is 1h.

After the roasting the calcine was cooled and weighted to calculate the calcine rate. Then the sulfur and arsenic content were analyzed to calculate the removal rates of sulfur and arsenic.

The acid leaching experiments were conducted in thermostatic magnetic agitator (DF-101S).

The acid leaching pulp was washed, filtered and dried. And the cake was ground for cyanide leaching.

The experiments of cyanide leaching were carried out by a JJ-1 type mechanical agitator.

The experimental condition of acid leaching and cyanide leaching are as follows.

The acid leaching experiment: liquid to solid rate 2:1, acid leaching acidity 50g/L, temperature 80℃, leaching time 2h.

The experiment of cyanide leaching: liquid to solid rate 2:1, pH 9.5(CaO), cyanide consumption 3kg/t, leaching time 24h.

After cyanidation leaching, the leaching cake was assayed to determinate of gold extraction rate.

3. RESULTS AND DISCUSSION

3.1. Effect of first stage roasting temperature

Figure 3 shows the influence of first stage roasting temperature on the desulfurization and dearsenization rates and the extraction rate of gold.

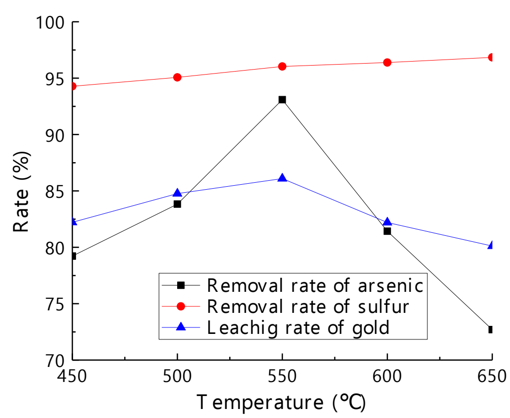


Figure 3. Effect of first stage roasting temperature

First stage excess-air coefficient 0.85, Second stage roasting temperature 650℃, and Second stage excess-air coefficient 1.1

As shown in **Figure 3**, the desulfurization rate is increased with the roasting temperature. The dearsenization rate is increased with the roasting temperature, but is decreased above 550℃.

If the roasting temperature is lower than 550℃ the oxidation of arsenopyrite is insufficient and some of arsenopyrite is fed to second stage roasting to oxidize to nonvolatile As_2O_5 due to high temperature and oxidizing atmosphere and form ferrous arsenate.

When the roasting temperature is higher than 550℃ the arsenopyrite is directly oxidized to As_2O_5 and the ferrous arsenate is formed to reduce the dearsenization rate and gold extraction rate.

When the roasting temperature is 550℃, the dearsenization rate and gold extraction rate are the highest, respectively 93.09%, 86%. Therefore, the optimal temperature of first stage roasting is 550℃ to maximize the gold extraction rate.

3.2 Effect of first stage excess-air coefficient

Figure 4 shows the influence of first stage excess-air coefficient on the desulfurization and dearsenization rates and the extraction rate of gold.

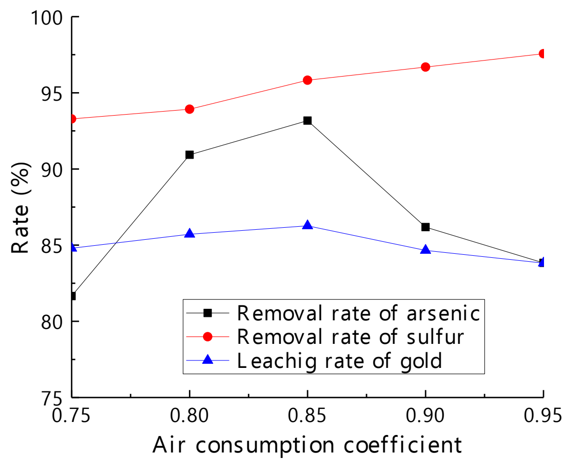


Figure 4. Effect of first stage excess-air coefficient

First stage roasting temperature 550℃, Second stage roasting temperature 650℃, Second stage excess-air coefficient 1.1

As shown in **Figure 4**, the change character of arsenic removal rate and gold extraction rate with excess-air coefficient is similar to the change character of its with roasting temperature.

If the excess-air coefficient is higher than 0.85, some of arsenic is oxidized to As_2O_5 to form ferrous arsenate. It causes the decrease of gold extraction rate.

When the excess-air coefficient is 0.85, the dearsenization rate and gold extraction rate are the highest, respectively 93.18%, 86%. Therefore, the optimal first stage excess-air coefficient is 0.85 to maximize the gold extraction rate.

3.3. Effect of second stage roasting temperature

Figure 5 shows the influence of second stage roasting temperature on the desulfurization and dearsenization rates and the extraction rate of gold.

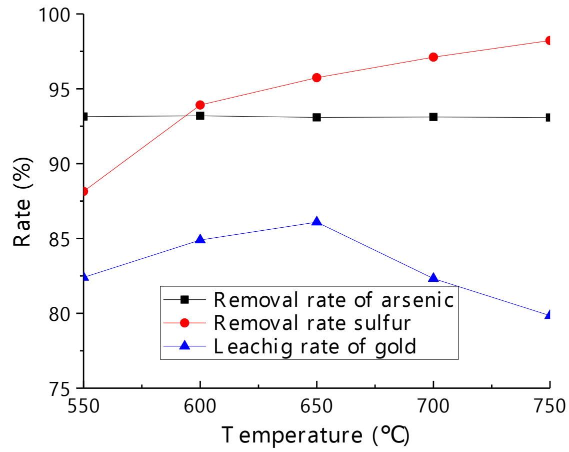


Figure 5. Effect of the second stage roasting temperature

First stage roasting temperature 550℃, First stage excess-air coefficient 0.85, Second stage excess-air coefficient 1.1

As shown in **Figure 5**, the desulfurization ratio is increased with rising of roasting temperature but the extraction rate of gold is decreased above 650℃. The effect of second stage roasting temperature on dearsenization rate is negligible.

To clear the reason of low gold extraction rate at high temperature, the specific surface area of calcine samples was measured by JW-BK type specific area analyzer.

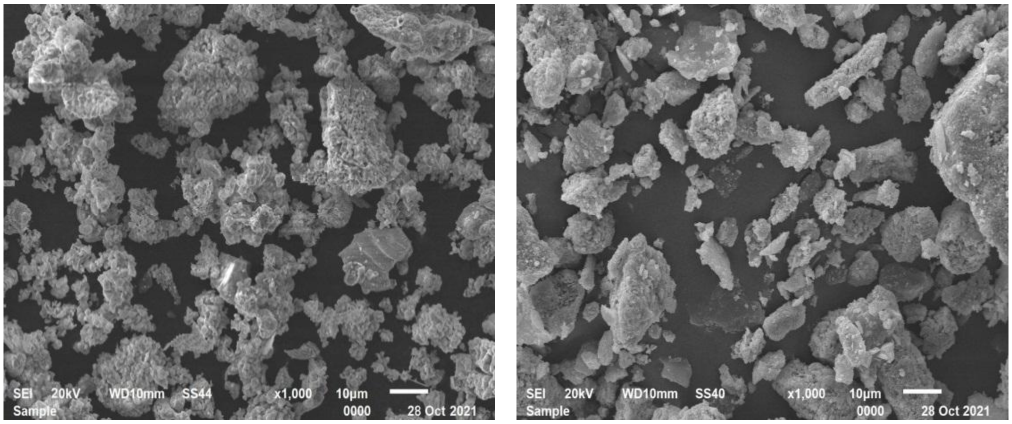
Table 3 shows the measurements of the specific surface area of calcine samples with the two-stage roasting temperature.

Table 3. Specific surface area of calcine samples

Roasting temperature, ℃	Specific area, m^2/g
550	3.26
650	5.97
750	2.56

As shown in **Table 3**, when the roasting temperature is 650℃, the specific surface area of calcine is the highest and is decreased again above it.

Figure 5 shows the SEM photograph of calcine samples with the two-stage roasting temperature.



a)- 650℃ b)- 750℃

Figure 5. SEM photograph of calcine samples

The SEM photograph of calcine samples showed that calcine sample at low roasting temperature became much rougher and much more porous than high roasting temperature. It is indicated that high temperature results decrease of the porosity of calcine in the roasting process.

These results indicate that high roasting temperature results decrease of specific surface area of roasted meaterial and gold extraction rate.

When the second stage roasting temperature is 650℃, the gold extraction rate is the highest, 86%. Therefore, the optimal second stage roasting temperature is 650℃ to maximize the gold extraction rate.

3.4 Effect of second stage excess-air coefficient

Figure 6 shows the influence of second stage excess-air coefficient on the desulfurization and dearsenization rates and the extraction rate of gold.

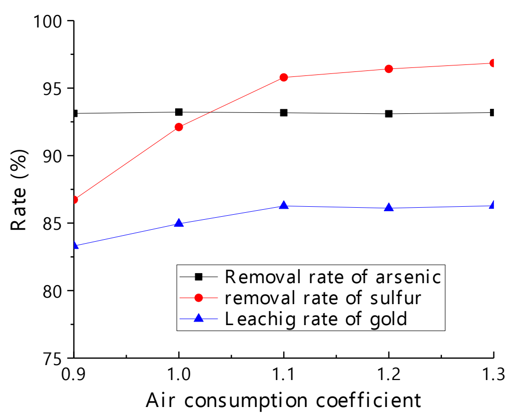


Figure 6. Effect of second stage excess-air coefficient

First stage roasting temperature 550℃, first stage excess-air coefficient 0.85, Second stage roasting temperature 650℃,

As shown in **Figure 6**, the desulfurization rate is increased with the excess-air coefficient but the extraction rate of gold is no change above 1.1.

If the excess-air coefficient is lower than 1.1, the gold extraction rate is low because the oxidation of sulfide is insufficient and the unroasted sulfide exists in calcine.

When the excess-air coefficient is 1.1, the gold extraction rate is the highest, 86%. Therefore, the optimal second stage excess-air coefficient is 1.1 to maximize the gold extraction rate.

4. CONCLUSIONS

(1) Roasting temperature and excess-air coefficient are main factors influenced on dearsenization rate and gold extraction rate. If the first stage roasting temperature is above 550℃ and the excess-air coefficient is higher than 0.85, the dearsenization rate is decreased and it causes decrease of gold extraction rate.

(2) In second stage roasting process the roasting temperature influences on specific surface area of calcine and gold extraction rate increases with increment of specific surface area. The second stage roasting temperature above 650℃ causes decreasing of the specific area of calcine and gold extraction rate.

(3) In the second stage roasting process the gold extraction rate increases with increment of excess-air coefficient.

5. ACKNOWLEDGMENT

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6. AUTHORS' NOTE

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Authors confirmed that the paper was free of plagiarism.

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