Title: METHOD FOR LEACHING GOLD FROM GOLD ORE CONTAINING PYRITE

Diagram:

- AA: Residual Au quality/g/t
- BB: FeS2 pyrolysis present
- CC: FeS2 pyrolysis absent (comparison)
- DD: Leaching time/h

Abstract:
The present invention improves the leaching speed of gold while also inhibiting the generation of sulfur dioxide in a method for leaching gold from gold ore containing pyrite without using highly poisonous chemicals such as cyanogen, thiourea, thiosulfuric.
(57) **Abstract (continued):**

acid, and halogen gas. A method for leaching gold involving: pre-treatment steps which include a step (1) for preparing a gold ore containing pyrite and a step (2) for heating the gold ore to 450°C or higher in a non-oxidizing atmosphere and for pyrolyzing the pyrite within the gold ore into iron sulfide (II) and elemental sulfur, and which does not include an oxidation roasting step; and a step (3) for leaching the gold component within the ore by bringing the gold ore that was subjected to the pre-treatment steps into contact with a gold leaching solution containing chloride ions, bromide ions, and iron ions while an oxidizing agent is supplied.
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(71) 出願人: J X日銅日石金属株式会社(JX NIPPO MINING & METALS CORPORATION) [JP]; 〒1008164 東京都千代田区大手町二丁目6番3号 Tokyo (JP).
(72) 発明者: 波多野 和浩(HATANO, Kazuhito); 〒3170056 茨城県日立市白銅1-1-2 J X日銅日石金属株式会社技術開発センター内 Ibaraki (JP). 田村 由樹(AOTO, Yukiko); 〒3170056 茨城県日立市白銅1-1-2 J X日銅日石金属株式会社技術開発センター内 Ibaraki (JP).
(74) 代理人: アクシス国際特許業務法人(AXIS PATENT INTERNATIONAL); 〒1050004 東京都港区新橋二丁目6番2号 新橋アイマークビル Tokyo (JP).

(54) Title: METHOD FOR LEACHING GOLD FROM GOLD ORE CONTAINING PYRITE
(54) 発明の名称: 黄鉄鉱を含む金鉱石からの金の浸出方法

(57) Abstract: The present invention improves the leaching speed of gold while also inhibiting the generation of sulfur dioxide in a method for leaching gold from gold ore containing pyrite without using highly poisonous chemicals such as cyanogen, thiourea, thiosulfuric acid, and halogen gas. A method for leaching gold involving: pre-treatment steps which include a step (1) for preparing a gold ore containing pyrite and a step (2) for heating the gold ore to 450°C or higher in a non-oxidizing atmosphere and for pyrolizing the pyrite within the gold ore into iron sulfide (II) and elemental sulfur, and which does not include an oxidation roasting step; and a step (3) for leaching the gold component within the ore by bringing the gold ore that was subjected to the pre-treatment steps into contact with a gold leaching solution containing chloride ions, bromide ions, and iron ions while an oxidizing agent is supplied.

(57) 要約: 黄鉄鉱を含む金鉱石からの金の浸出方法において、毒性の高いシアノ化、チオ尿素、チオ亜硫酸、ハロゲンガスといった薬品を使用することなく、更にはニ酸化硫黄の発生を抑制しながらも金の浸出速度を向上する。黄鉄鉱を含有する金鉱石を準備する工程1、及び、当該金鉱石を非酸化性雰囲気下で450℃以上に加熱し、当該金鉱石中の黄鉄鉱を硫化鉄及び単体硫黄に熱分解する工程2を含み、酸化焙焼工程を含まない前処理と、前処理工程後の金鉱石を、塩化物イオン、臭化物イオン、及び亜イオンを含有する金浸出液に酸化剤の供給で接触させて、当該鉱石中の金成分を浸出する工程3を含む金の浸出方法。
添付公開書類：
—— 国際調査報告（条約第 21 条(3)）
SPECIFICATION

>Title of the invention
Method for leaching gold from gold ore containing pyrite

>Technical background
[0001]
The present invention relates to a method for leaching gold from gold ore which contains pyrite.
[0002]
As a method for leaching gold from sulfide ore containing gold, a technique relying on the hydrometallurgical process is known. Traditionally, the leaching of gold from the sulfide ore has been conducted by using reagents such as cyanide, thiourea, thiosulfate, halogen gas or the like. Recently, a gold-leaching solution containing chloride ions, iron ions, copper ions and bromide ions is used as a less toxic leaching solution as described in Japanese Patent Application Publication No. 2008-106347 (Patent document 1) and Japanese Patent Application Publication No. 2009-235525 (Patent document 2).
[0003]
Further, as a pretreatment for facilitating the leaching of gold from sulfide ore, the process of subjecting sulfide ore to oxidizing roasting is known. Recently, pretreatment combining the oxidizing roasting process with another process has been proposed. For example, Japanese Patent Application Publication No. 2010-235999 (Patent Document 3) proposed a process of subjecting copper sulfide ore to leaching at the temperature below the melting point of the sulfur, and allowing the resulting fine sulfur particles and remaining non-leached particles to float up from the leached residue through utilization of the difference in their hydrophobicity, separating iron oxide or gangue by precipitation or as tailing ores, whereby the gold contained in the residual solution is condensed. Thereafter, the condensed components containing gold is subjected to sulfur removal and
then oxidizing roasting so as to transform the iron component into iron oxide (hematite) which, in turn, is dissolved in sulfuric acid, whereby the residue containing the concentrated gold is recovered.

[0004]

With respect to pyrite only, it has been known that pyrite pyrolizes into pyrrhotite, which is readily soluble to acid, and sulfur. Japanese Patent Application Publication No. 2005-042155 (Patent document 4) suggests utilizing the reaction to remove pyrite from the residue obtained after leaching copper sulfide ore containing pyrite and to enrich the noble metal.

[Prior art literatures]

[0005]


[0006]

[Summary of the invention]

[Problem to be solved by the invention]

The process disclosed in Japanese Patent Application Publication No. 2009-235525 (Patent document 2), which does not use highly toxic cyanide, thiourea, thiosulfate, halogen gas, or the like and facilitates leaching of the gold contained in copper sulfide ore, is highly practical for leaching the gold included in the copper sulfide concentrate. When this process is applied to the pyrite ore, the gold leaching speed is not sufficient.

[0007]

As such, a pretreatment which uses the oxidizing roasting by supplying oxygen as disclosed in Japanese Patent Application Publication
No. 2010-235999 (Patent document 3) is considered to remove sulfur in advance and to facilitate iron leaching.

[0008]

However, if the process of the oxidizing roasting of sulfide ore, including the process disclosed in the Patent document 3, is adopted, the following chemical reactions, $2\text{CuS}+2\text{O}_2\rightarrow2\text{CuO}+\text{SO}_2$, $2\text{CuFeS}_2+6\text{O}_2\rightarrow\text{CuO}+4\text{SO}_2+\text{Fe}_2\text{O}_3$ and $4\text{FeS}_2+11\text{O}_2\rightarrow2\text{Fe}_2\text{O}_3+8\text{SO}_2$ will occur predominantly, and accordingly the problem of generation of sulfur dioxide ($\text{SO}_2$), which is known as environmental contaminant, cannot be avoided. As for a pretreatment for enhancing the gold-leaching rate, it is desirable, from the aspects of the safety and the protection of the environment, to decrease the sulfur dioxide which is generated during a treatment process of ores for gold-leaching for enhancing the safety and reducing the influence on the environment.

[0009]

The Patent document 4 is related to a process predicated on recovering noble metal with pyrometallurgy in view of the problem residing in recovering noble metal with hydrometallurgy. As such, there is no supposition that noble metal should be leached with a hydrometallurgical process (see paragraphs 0007-0008, 0078 of the patent document 4). Further, it does not suggest the effect achieved by utilizing a hydrometallurgical process at all.

[0010]

In any event, the method for pretreating pyrite with a thermal reaction may generate iron that is soluble to acid by removing sulfur value but toxic gas will generate during the thermal reaction or dissolution of iron. In addition, it is pyrite that is leached and removed, which may contribute to improvement of gold grade in the raw material but necessitates gold refining separately.

[0011]

Therefore, the present invention is proposed under the above-mentioned situations, and has an object of providing a process for
efficiently leaching gold from gold ore containing pyrite (FeS₂), without using such reagents as toxic cyanide, thiourea, thiosulfate, halogen gas, and has an object of enhancing the gold-leaching speed while suppressing the generation of sulfur dioxide.

[Means for solving the problem]

[0012]

The present inventors have conducted intensive studies on the above-mentioned problems and have found that, by adopting a pretreatment of pyrolyzing pyrite ore into iron (II) sulfide under a non-oxidative atmosphere, and thereafter leaching the gold using a gold-leaching solution containing halide ions and ferric ions, the generation of sulfur oxide is suppressed and the gold-leaching speed is drastically increased.

[0013]

The present invention is based on the above-mentioned discovery and, in one aspect, provides a process for leaching gold comprising:

- a pretreatment including step 1) of preparing gold ore containing pyrite and step 2) of heating the gold ore under a non-oxidative atmosphere to 450°C or more to pyrolyze the ore into iron (II) sulfide and elemental sulfur, wherein the pretreatment does not include oxidizing roasting, and

- step 3) of contacting the pretreated gold ore with a gold leaching solution containing halide ions and iron ions while supplying an oxidant to leach gold component in the ore.

[0014]

In one embodiment of the gold leaching method according to the present invention, the gold-leaching solution contains chloride ions and bromide ions.

[0015]

In another embodiment of the gold-leaching method according to the present invention, the gold leaching in the step 3 is carried out under the condition of retaining an oxidation-reduction potential (reference electrode is Ag/AgCl electrode) at 550 mV or more.

[0016]
In a further embodiment of the gold-leaching method according to the present invention, the pyrolysis in the step 2 is carried out under the conditions of retaining the gold ore at 600-750°C for 5-60 minutes.

[0017]

In a further embodiment of the gold leaching method according to the present invention, the content of the pyrite in the gold ore is 5-80 mass%.

[0018]

In a further embodiment of the gold leaching method according to the present invention, the elemental sulfur generated in the step 2 which is in the form of gas is separated from the gold ore by solid-gas separation.

[0019]

In a further embodiment of the gold leaching method according to the present invention, the iron (II) sulfide and elemental sulfur generated in the step (2) are both recovered as solids after cooling and subjected to the leaching step by bringing them into contact with the gold leaching solution together.

[0020]

In a further embodiment of the gold leaching method according to the present invention, the gold-leaching is conducted while the pH of the leaching solution is kept at most 1.9.

[Effect of the invention]

[0021]

By conducting the pretreatment according to the present invention on the gold ore containing the pyrite ore and then conducting the gold leaching with a specific gold-leaching solution, a remarkably improved gold-leaching speed can be attained, while the generation of noxious sulfur oxide is suppressed. In other words, the present invention provides a highly practical gold-leaching process which excels in the safety and preservation of the environment.

[Brief explanation of the drawings]

[0022]

Fig. 1 is a graph showing the relation between the leaching time and
the Au grade in the residues with respect to the example and comparative example.

Fig. 2 is a TG/DTA curve obtained during thermal analysis under a nitrogen atmosphere for ground pyrite concentrate used in Example 1. [Mode of practicing the invention]

[0023]

The present invention will be explained in details in the following.

[0024]

1. Pretreatment

One embodiment of pretreatment of the gold ore according to the present invention includes step 1 of preparing gold ore containing pyrite and step 2 of heating the gold ore under a non-oxidative atmosphere at 450°C or more to pyrolyze the pyrite in the gold ore into iron (II) sulfide and elemental sulfur, but not includes oxidizing roasting.

[0025]

(1) Step 1

In the step 1, gold ore containing pyrite is prepared. This is because the present invention aims at the enhancement of the leaching ratio of gold in the pyrite, which is refractory and low in the gold-leaching ratio. However, the other conditions, such as the concentration of gold in the ore, for example, are not required. The gold ore, which is the object of treatment, may be those having been subjected to conventional beneficiation such as floatation or gravity separation. It is also possible to grind the ore to smaller particle sizes so that the contact of gold-leaching solution with gold within the ore is facilitated. The gold concentration of the gold ore is typically in the order of 0.1-100 ppm by mass, and more typically in the order of 1-20 ppm by mass.

[0026]

Gold ore may contain chalcopyrite, galena, sphalerite, arsenopyrite, antimonite, pyrrhotite, and the like other than pyrite. In a typical example of the present invention, gold ore containing at least 3 mass% of pyrite,
more typically at least 30 mass% of pyrite is used. By using such gold ore, the effect of the pretreatment of the present invention is remarkably exhibited. There is no particular upper limit to the content of the pyrite in the gold ore and 100 mass% is allowable but typically the content is at most 80 mass%.

[0027]

Another feature of the present invention is that the oxidizing roasting process is not included. In the conventional technique, the ores were subjected to oxidizing roasting under the presence of the oxygen or air, and hence the sulfur contained in the sulfide ores is combined with the oxygen, resulting in generation of sulfur oxide. In contrast, the present invention does not perform such oxidizing roasting process.

[0028]

(2) Step 2

In the step 2, the gold ore is heated to at least 450°C under a non-oxidative atmosphere to pyrolyze the pyrite in the gold ore into iron (II) sulfide and elemental sulfur. This reaction is expressed by the formula: FeS₂ → FeS+S. Theoretically, there is no generation of sulfur oxide but, in actual cases, complete shielding of oxygen may be practically difficult in some cases. Also, in the practical operation, if the generation of sulfur oxide remains within the extent that it does not have any significant influence, no sulfuric acid production facility will be required for its treatment. Such atmosphere may be called as a non-oxidative atmosphere. Thus, the non-oxidative atmosphere of the reaction system according to the present invention allows the presence of an unavoidable amount of leak-in oxygen. For example, if the molar ratio of oxygen supply to the pyrite is oxygen:pyrite=1:5 or less, the presence of oxygen is permitted and preferably oxygen:pyrite=1:10 or less. The pyrolyzed gold ore exhibits remarkably enhanced solubility to the gold leaching solution as explained hereafter. The dissolution rate of gold increases by approximately ten times than the case without pyrolysis. In the pyrolysis according to the present invention, since pyrite (FeS₂) is not converted to hematite (Fe₂O₃), it was
anticipated that the rate of gold-leaching would not be sufficient. Therefore, it was quite amazing that such remarkable result has been obtained.

[0029]

As the non-oxidative atmosphere for conducting the pyrolysis, reductive atmosphere such as ammonia, carbon monoxide and hydrogen sulfide, and inert atmosphere such as rare gas (e.g. argon or helium), nitrogen and carbon dioxide may be cited. Among them, inert atmosphere is preferable in terms of preventing unexpected reaction to occur. Alternatively, the exhausted gas used in the pyrolysis may be recycled. If oxygen is contained in the atmosphere, the gold ore is subjected to oxidizing roasting, thereby generating sulfur dioxide which could pollute the environment. Hence, the present invention does not use oxygen.

[0030]

During the pyrolysis, it is necessary to maintain the temperature of the gold ore at least 450°C. This is because the pyrolysis of the pyrite is difficult to proceed at a temperature lower than 450°C. Preferably, pyrolysis is performed while keeping the temperature at least 550°C and more preferably keeping the temperature at least 650°C. Also, it is preferable to keep the retention temperature for at least 5 minutes, and more preferably for at least 30 minutes. This is to sufficiently progress the pyrolysis reaction. However, if the temperature of the gold ore is excessively high, the energy for heating the ore and the processing time become too excessive, and accordingly the retention temperature is preferably 800°C or less, and more preferably 750°C or less. Similarly, the retention time of maintaining the retention temperature is preferably 120 minutes or less, more preferably 60 minutes or less.

[0031]

Although there is no particular restriction to the types of the heating furnace for the pyrolysis, a tubular furnace or a rotary kiln, for example, may be used.

[0032]

The elemental sulfur generated by pyrolysis is gasified in the high
temperature furnace and accordingly the elemental sulfur can be subjected to solid/gas separation and can be then delivered together with the atmospheric gas to a venting system. However, if the elemental sulfur is sent to the venting system, the sulfur will deposit with the lowering temperature and might cause trouble such as clogging of the gas flue. Therefore, it is desired to recover the sulfur with a wet scrubber. Alternatively, the gaseous elemental sulfur may be cooled together with the iron (II) sulfide generated in the step 2. In this case, they are recovered as solids, which in turn are sent together to the gold-leaching step. The elemental sulfur is separated in the leaching step as leaching residue without interfering with the leaching of gold. In this case, this process is economical because the wet scrubber becomes unnecessary.

[0033]

2. Gold leaching step

In one embodiment of the gold leaching method according to the present invention, the step 3 of contacting the pretreated gold ore with a gold leaching solution containing halide ions and iron ions while supplying an oxidant, thereby leaching the gold component in the ore.

[0034]

The leaching of gold proceeds as follows. The dissolved gold reacts with halide ions or bromide ions to form a halide complex of gold.

[0035]

Though chloride ions may be singly used as the halide ions in the gold-leaching solution, it is preferable to contain bromide ions. the combined use of bromide ions allows formation of complex at a lower oxidation-reduction potential, enhancing the leaching efficiency of gold.

[0036]

In addition, dissolution of iron sulfide generated in the pretreatment stage will also proceed simultaneously with gold leaching. Accordingly, gold confined in the original ore is brought into contact with the leaching solution and is dissolved. Further, iron ions in the form of trivalent iron ions formed under supply of oxidant, or trivalent iron ions from the
beginning, functions to oxidize the gold and to immediately oxidize hydrogen sulfide generated by the reaction with acid to sulfur. Furthermore, Fe$^{2+}$ generated by dissolution of iron sulfide will be also oxidized to Fe$^{3+}$ under the supply of an oxidant.

The gold-leaching solution preferably contains copper ions. Although the copper ions do not directly participate in the reaction, the oxidation of the iron ions is accelerated in the presence of the copper.

The method for contacting a leaching solution with gold ore includes sprinkling method, immersion method or the like but there is no particular restriction. However, from the standpoint of the reaction efficiency, a method of immersing and agitating the residue in the leaching solution is preferred.

As the source of chloride ions, though there is no particular restriction, hydrogen chloride, hydrochloric acid, metal chloride and chlorine gas, etc. may be cited for instance. From the aspects of economy and safety, it is preferable to feed the ions as metal chloride. Cited as metal chloride are copper chloride (cuprous chloride, cupric chloride), iron chloride (ferrous chloride, ferric chloride), chloride of alkaline metal (lithium, sodium, potassium, rubidium, cesium, francium), chloride of alkaline-earth metal (beryllium, magnesium, calcium, strontium, barium, radium) can be cited. Sodium chloride is preferred from the standpoint of the cost and easy availability. It is also preferable to use copper chloride and iron chloride because they are utilized also as sources of copper ions and iron ions.

As the source of the bromide ions, though there is no particular restriction, hydrogen bromide, hydrobromic acid, metal bromide and bromine gas may be mentioned. As metal bromide, copper bromide (cuprous bromide and cupric bromide), iron bromide (ferrous bromide, ferric
bromide), bromide of alkaline metal (lithium, sodium, potassium, rubidium, cesium and francium), bromide of alkaline earth metal (beryllium, magnesium, calcium, strontium, barium, radium), and from the economical standpoint and easy availability, sodium bromide is preferred. Also, copper bromide and iron bromide are preferred because they can be used as sources of copper ions and iron ions.

[0041]

Copper ions and iron ions are usually supplied in the form of their salts, for example, a halide salt. The copper ions are preferably supplied in the form of copper chloride and/or copper bromide, and the iron ions are preferably supplied in the form of iron chloride and/or iron bromide, from the standpoint that they can be also used as sources of chloride ions and/or bromide ions. As the copper chloride and iron chloride, it is preferable to use cupric chloride (CuCl₂) and ferric chloride (FeCl₃), respectively, but cuprous chloride (CuCl) and ferrous chloride (FeCl₂) may also be used without a significant disadvantage because they are respectively oxidized into cupric chloride (CuCl₂) and ferric chloride (FeCl₃), by supplying oxidant to the leaching solution.

[0042]

The concentration of the chloride ions in the gold leaching solution used in the step 3 is preferably 30g/L·180g/L. The concentration of the bromide ions in the gold leaching solution is preferably 1g/L·100g/L from the standpoints of the reaction rate and the solubility, and more preferably 10g/L·40g/L from the economical standpoint. And, the total concentration of the chloride ions and bromide ions is preferably 80g/L·200g/L.

[0043]

The oxidation-reduction potential (vs. Ag/AgCl) of the leaching solution at the beginning of the step 3 is preferably at least 550mV, more preferably at least 600mV, from the standpoint of acceleration of the gold leaching.

[0044]

Also, to enhance the gold leaching speed, the pH of the leaching
solution is preferably maintained at 2.0 or less. But the oxidation rate of
iron is promoted at higher pH and hence the pH is more preferably
maintained at 0.5-1.9. The temperature of the gold leaching solution is
preferably at least 45°C, and more preferably at least 60°C from the
standpoint of acceleration of the gold leaching. However, excessively high
temperature will cause evaporation of the leaching solution or increase the
costs for heating, and accordingly 95°C or less is preferable and 85°C or less
is more preferable.

[0045]

Accordingly, in a preferred embodiment of the present invention, a
mixed solution containing at least one of hydrochloric acid and hydrobromic
acid, at least one of the cupric chloride and cupric bromide, at least one of
ferric chloride and ferric bromide, and at least one of sodium chloride and
sodium bromide may be used as the gold-leaching solution in the step 3 on
the condition that both of chloride ions and bromide ions are contained in
the leaching solution.

[0046]

The oxidation-reduction potential is controlled by supplying the
oxidant while conducting the gold leaching step 3. If the oxidant is not
supplied, the oxidation-reduction potential will be decreased and thus the
leaching reaction will not proceed. Though there is no particular restriction
to the oxidant, oxygen, air, chlorine, bromine and hydrogen peroxide or the
like may be cited. An oxidant having excessively high oxidation-reduction
potential is not necessary and the air is sufficient. The air is preferred from
the standpoint of the cost and safety.

[0047]

After pretreatment but before the gold leaching step 3, various
treatments for removing impurities in the gold ore may be performed. For
example, elemental sulfur can be removed by heating the pretreated gold
ore to a temperature at which the elemental sulfur is molten and then
separating the elemental sulfur and gold by filtration. Iron sulfide (FeS)
can be removed by contacting the pretreated gold ore with sulfuric acid,
hydrochloric acid or other mineral acids, or with an aqueous solution containing Fe$^{3+}$ salt such as iron sulfate or iron chloride so as to leach iron component, and then subjecting it solid/liquid separation.

[0048]

After the leaching of gold and the subsequent solid/liquid separation, gold can be recovered from the resulting gold solution. Though there is no particular restriction to the method for recovering the gold, adsorption on activated carbon, electrowinning, solvent extraction, reduction, cementation and ion exchange or the like may be utilized. Sulfur component may remain as sulfate, sulfide and elemental sulfur in the post-leaching solution but the gold leached in the solution can be separated from them by solvent extraction.

[0049]

Further, it is also effective to recover gold during the leaching reaction, whereby the concentration of gold in the leaching solution is decreased, as a result the leaching ratio of gold increases. This can be performed by providing for activated carbon with or without lead nitrate into the gold leaching solution during the leaching reaction.

[Examples]

[0050]

In the following, the present invention will further be specifically explained by way of working examples. It should be noted that the present invention is not restricted to the examples. The analysis of the metals used in the working examples was performed according to ICP-AES. However, the analysis of the gold used in the examples was conducted according to ICP-AES for quantitative analysis after causing deposition of gold in the specimens by cupellation process.

[0051]

[Comparative Example 1]

Pyrite ore concentrate (produced in Papua New Guinea) was prepared. The content of pyrite in this pyrite ore concentrate was determined by XRD and chemical analysis, and 17 mass% of pyrite was
confirmed. The pyrite ore concentrate was milled and ground in a ball mill to adjust the particle size to 24μm at the particle size d80, namely, the particle size at which the cumulative weight becomes 80% in the distribution curve of cumulative weight particle sizes. The d80 was the average of three measurements which were conducted using the laser diffraction particle size distribution analyzer (Shimadzu Corporation Model No. SALD2100). Subsequently, leaching operation was conducted on the ground pyrite ore concentrate (200g), using a hydrochloric acidic gold leaching solution having the composition as listed in Table 1, with pulp concentration of 100 g/L at a temperature of 85°C for 90 hrs. Air was blown in (0.1 L/min per 1L of the concentrate) during the leaching operation with continuous agitation and the oxidation-reduction potential (ORP: vs. Ag/AgCl) was maintained at 530mV or higher. Also, during the leaching, the pH of the gold leaching solution was maintained at 1.0-1.1 by appropriately adding hydrochloric acid.

[0052]

TABLE 1

<table>
<thead>
<tr>
<th></th>
<th>Gold leaching solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>FeCl₃•6H₂O(g/L)</td>
<td>10</td>
</tr>
<tr>
<td>CuCl₂•2H₂O(g/L)</td>
<td>48</td>
</tr>
<tr>
<td>NaCl(g/L)</td>
<td>25</td>
</tr>
<tr>
<td>NaBr(g/L)</td>
<td>103</td>
</tr>
<tr>
<td>All chloride ions(g/L)</td>
<td>40</td>
</tr>
<tr>
<td>All bromide ions(g/L)</td>
<td>80</td>
</tr>
<tr>
<td>ORP(mV) (vs.Ag/AgCl)</td>
<td>717</td>
</tr>
<tr>
<td>pH</td>
<td>1.52</td>
</tr>
</tbody>
</table>

[0053]

During the leaching test, samples of the leaching residue were periodically taken and the Au grade was determined. Fig. 1 shows the relation between the leaching time versus Au grade in the residue obtained
from the test. Refer to the plotting of FeS₂ (refer to the plot of "without FeS₂ pyrolysis" in Fig. 1). From this result, it is ascertained that it took 90 hours for the Au grade in the residue, which was approximately 6g/t at the start, to decrease to 0.9g/t.

[0054]

<Example 1>

The ground pyrite ore concentrate (1.5kg) which was identical with that of Comparative Example 1 was charged in a tubular furnace and one hour was spent to raise the temperature to 700°C (the rate of temperature increase=10°C/min) under the nitrogen atmosphere. It was thereafter heated for one hour. After allowing it cool to a room temperature, it was confirmed that the peak of FeS₂ contained in the original ore had disappeared and a peak of FeS had been found by the XRD analysis before and after the heat treatment, the elemental sulfur resulting from the heat treatment was not particularly removed.

Subsequently, using a hydrochloric acidic solution of the gold-leaching solution having the same composition as in Comparative Example 1, leaching was conducted on the heat-treated pyrite ore concentrate with pulp concentration of 100g/L at the solution temperature of 85°C for 18 hours. Air was blown during the leaching (at the rate of 0.1L/min per 1L of the concentrate) while agitation was kept and the oxidation-reduction potential (ORP: vs Ag/AgCl) was maintained at least 400mV. During the leaching, hydrochloric acid was appropriately added to keep the pH of the gold-leaching solution at 1.0-1.1.

[0055]

During leaching test, samples of the leaching residue were periodically taken and the Au grade was determined. Fig. 1 shows the relation between the leaching time versus Au grade in the residue obtained from the test (refer to the plot of "with FeS₂ pyrolysis" in Fig. 1). From this result, it is ascertained that it took only 12 hours for the Au grade in the residue, which was approximately 6g/t at the start, to decrease to 0.6g/t.

[0056]
The change in the FeS\textsubscript{2} and FeS peak in the XRD caused by pyrolysis condition

Using 1.5 kg of the ground pyrite ore concentrate used in Example 1, the changes in the diffraction intensities of FeS\textsubscript{2} and FeS in the XRD analysis were observed when the retention temperature and the retention time was changed. The test was conducted using a tubular furnace under the nitrogen atmosphere. The elemental sulfur generated by pyrolysis was evaporated and purged by a nitrogen stream. The temperature was increased at a rate of 10\degree C/min for all tests. Cooling was conducted by allowing it cool to a room temperature. The XRD analysis was conducted with type “RINT2200 ultimate” manufactured by Rigaku Corporation. FeS\textsubscript{2} has characteristic peaks at $2\theta = 32.98^\circ$ and $56.15^\circ$. FeS has characteristic peaks at $2\theta = 43.67^\circ$ and $33.78^\circ$. Accordingly, attention was given to these incident angles. The results are shown in Table 2.

<table>
<thead>
<tr>
<th>Heating Condition</th>
<th>FeS\textsubscript{2} intensity (CPS)</th>
<th>FeS intensity (CPS)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$32.98^\circ$</td>
<td>$56.15^\circ$</td>
</tr>
<tr>
<td>Before heat treatment</td>
<td>250</td>
<td>170</td>
</tr>
<tr>
<td>550</td>
<td>60</td>
<td>270</td>
</tr>
<tr>
<td>550</td>
<td>120</td>
<td>60</td>
</tr>
<tr>
<td>600</td>
<td>5</td>
<td>ND</td>
</tr>
<tr>
<td>600</td>
<td>30</td>
<td>ND</td>
</tr>
<tr>
<td>600</td>
<td>60</td>
<td>ND</td>
</tr>
<tr>
<td>650</td>
<td>60</td>
<td>ND</td>
</tr>
<tr>
<td>700</td>
<td>60</td>
<td>ND</td>
</tr>
</tbody>
</table>

ND: Less than detectable limit

From the results listed in Table 2, it is confirmed that the peaks assigned to pyrite disappeared when it was heated to at least 600\degree C. This
means that the crystalline pyrite is pyrolyzed and shows that the retention
temperature of at least 650°C and the retention time of at least 60 minutes
are the most preferred because of the appearance of clear peaks of FeS in
these conditions.
[0059]
<Example 2>

The ground pyrite ore concentrate (1.5kg) which was identical with
that of Comparative Example 1 was charged in a tubular furnace and one
hour was spent to raise the temperature to 700°C (the rate of temperature
increase=10°C /min) under the nitrogen atmosphere. It was thereafter
heated for one hour. After allowing it cool to a room temperature, a
leaching operation was conducted using a hydrochloric acidic gold leaching
solution having the composition as listed in Table 3 with pulp concentration
of 100 g/L at a temperature of 85°C. Air was blown in (0.1 L/min per 1L of
the concentrate) during the leaching operation with continuous agitation
and the oxidation-reduction potential (ORP: vs. Ag/AgCl) was maintained at
600mV or higher. However, a leaching operation under the same condition
except that NaBr was not added was also carried out. Samples of the
leaching solution were periodically taken and the Au grade was determined.
Also, during the leaching, the pH of the gold leaching solution was
maintained at 1.0~1.1 by appropriately adding hydrochloric acid.
[0060]
<Comparative Example 2>

The ground pyrite ore concentrate (1.5kg) which was identical with
that of Comparative Example 1 was subjected to leaching using the
hydrochloric acidic gold leaching solution having the same composition as
Example 2 with pulp concentration of 100 g/L at a temperature of 85°C. Air
was blown in (0.1 L/min per 1L of the concentrate) during the leaching
operation with continuous agitation and the oxidation-reduction potential
(ORP: vs. Ag/AgCl) was maintained at 600mV or higher. However, a
leaching operation under the same condition except that NaBr was not
added was also carried out. Samples of the leaching solution were
periodically taken and the Au grade was determined. Also, during the leaching, the pH of the gold leaching solution was maintained at 1.0·1.1 by appropriately adding hydrochloric acid.

[0061]

[TABLE 3]

<table>
<thead>
<tr>
<th></th>
<th>Gold leaching solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>FeCl₃·6H₂O(g/L)</td>
<td>10</td>
</tr>
<tr>
<td>CuCl₂·2H₂O(g/L)</td>
<td>48</td>
</tr>
<tr>
<td>NaCl(g/L)</td>
<td>250</td>
</tr>
<tr>
<td>NaBr(g/L)</td>
<td>26</td>
</tr>
<tr>
<td>All chloride ions(g/L)</td>
<td>180</td>
</tr>
<tr>
<td>All bromide ions(g/L)</td>
<td>20</td>
</tr>
<tr>
<td>ORP(mV) (vs.Ag/AgCl)</td>
<td>717</td>
</tr>
<tr>
<td>pH</td>
<td>1.52</td>
</tr>
</tbody>
</table>

[0062]

Table 4 shows leaching time and leaching ratio of gold for Example 2 and Comparative Example 2.

[0063]

[TABLE 4]

<table>
<thead>
<tr>
<th>leaching time and leaching ratio of gold</th>
<th>Bath composition of Table 3 without NaBr</th>
<th>Bath composition of Table 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Comparative Example 2</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leaching time (h)</td>
<td>&gt;150</td>
<td>90</td>
</tr>
<tr>
<td>Leaching ratio (%)</td>
<td>&lt;50</td>
<td>86</td>
</tr>
<tr>
<td><strong>Example 2</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leaching time (h)</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>Leaching ratio (%)</td>
<td>81</td>
<td>86</td>
</tr>
</tbody>
</table>
[0064] As mentioned above, when gold ore containing pyrite is leached with a chloride bath containing Fe$^{3+}$ and Cu$^{2+}$ (Table 4, Comparative Example 2), the leaching speed of gold is not sufficient. However, according to the present invention, the leaching speed of gold is remarkably improved as shown by the result of Example 2. Furthermore, it is also ascertained that a relatively higher gold leaching ratio can be attained in a short period even when the leaching solution does not contain bromide ions.

[0065] <Example 3: The temperature at which pyrolysis occurs.>

On the ground pyrite ore concentrate used in Example 1, the weight change and the endothermic/exothermic heat at respective temperatures were monitored, using the thermal analysis device (Model TG/DTA6300 manufactured by Seiko). The results are shown in Fig. 2. From the fact that the mass decrease begins at 450°C and simultaneously the change of calorific value is observed. It is confirmed that the pyrolysis of the pyrite begins. Under the nitrogen atmosphere, pyrolysis does not occur until the temperature reaches 450°C. It should be noted that, from the results of the XRD analysis, a long period of time is necessary for pyrolisys and accordingly heat treatment at 600°C or higher is desirable.
CLAIMS

1. A process for leaching gold comprising:
   a pretreatment including step 1) of preparing gold ore containing pyrite and step 2) of heating the gold ore under a non-oxidative atmosphere to 450°C or more to pyrolyze the pyrite in the gold ore into iron (II) sulfide and elemental sulfur, wherein the pretreatment does not include oxidizing roasting, and
   step 3) of contacting the pretreated gold ore with a gold leaching solution containing halide ions and iron ions while supplying an oxidant to leach gold component in the ore.

2. A process for leaching gold according to claim 1, wherein the gold leaching solution contains chloride ions and bromide ions.

3. A process for leaching gold according to claim 1 or 2, wherein the gold leaching in the step 3 is carried out under the condition of retaining an oxidation-reduction potential (reference electrode is Ag/AgCl electrode) at 550 mV or more.

4. A process for leaching gold according to claim 1 or 2, wherein the pyrolysis in the step 2 is carried out under the conditions of retaining the gold ore at 600-750°C for 5-60 minutes.

5. A process for leaching gold according to any one of claims 1-3, wherein the content of the pyrite in the gold ore is 5-80 mass%.

6. A process for leaching gold according to any one of claims 1-4, wherein the elemental sulfur generated in the step 2 which is in the form of gas is separated from the gold ore by solid-gas separation.

7. A process for leaching gold according to any one of claims 1-4,
wherein the iron (II) sulfide and elemental sulfur generated in the step (2) are both recovered as solids after cooling and subjected to the leaching step by bringing them into contact with the gold leaching solution together.

8. A process for leaching gold according to any one of claims 1-6, wherein the gold leaching is conducted while the pH of the leaching solution is kept at most 1.9.
[Fig. 1]

A plot showing the Au grade in the residue (g/t) over leaching time (h) with and without FeS₂ pyrolysis:
- Solid circles with FeS₂ pyrolysis
- Triangle with FeS₂ pyrolysis (comparison)

Key:
- 6.7 with FeS₂ pyrolysis
- 3.3 without FeS₂ pyrolysis
- 0.6 without FeS₂ pyrolysis
AA  Residual Au quality/g/t
BB  FeS2 pyrolysis present
CC  FeS2 pyrolysis absent (comparison)
DD  Leaching time/h