



Selective chalcopyrite flotation from pyrite with glycerine-xanthate as depressant



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ABSTRACT

Micro-flotation tests, adsorption, electrokinetic and FTIR measurements were carried out in order to investigate the selective depression mechanism of sodium glycerine-xanthate (SGX) on pyrite in chalcopyrite flotation. The flotation results showed a large difference in chalcopyrite (>85%) and pyrite (<30%) recovery as stirred pulp-mixing with SGX before the addition of collector sodium butyl xanthate (SBX), at the range of pH 7–10. A much stronger adsorption of SGX on pyrite than chalcopyrite was dramatically revealed by zeta potential measurements, which can explain the better floatability of chalcopyrite than pyrite. The adsorption of SBX onto pyrite was depressed intensely while that onto chalcopyrite was affected slightly when SGX was used as depressant, because of more stronger adsorption between SGX and SBX occurring onto the pyrite surfaces. The absorbed amount of SGX on chalcopyrite increases slightly, over the pH range from 3 to 12, while that on pyrite increases rapidly with the increased SGX concentration, which is consistent with the flotation results. FTIR reflection spectroscopic measurements further demonstrated the depression effect of pre-absorbed SGX on SBX adsorption, which is attributed to its hydrophilic hydroxyl groups.

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1. Introduction

Refractory copper sulfide ores are typically characterized as being low grade with complex mineralogy and with the valuable Cu sulfide minerals being fine-grained (Qiu et al., 1997). The objective of the flotation on copper-sulfur ores is to achieve separation of copper minerals from iron sulfide and gangue minerals. Pyrite is one of the main iron sulfide minerals in chalcopyrite ores (Qiu et al., 2006), so to some extent, the success of the separation of Cu sulfide minerals and pyrite is often determined by the floatability of the pyrite. Generally, the technique of floating copper sulfide minerals with pyrite depression under alkaline medium is adopted in the separation of them. Therefore, it becomes a critical assignment to seek out selective depressants that strongly depress the pyrite flotation but have little effect on the floatability of chalcopyrite. However, pyrite is easily-floated and its floatability changes in different mineral deposits, where the surface structure inhomogeneity and lattice defect of pyrite are discrepant (Chandra and Gerson, 2009; Karthe et al., 1993). These characteristics of pyrite create difficulties for finding efficient depressants which can be applied in mineral processing circuits.

Traditional depressants used in the flotation of copper sulfide minerals from pyrite are inorganic, including lime, calcium hypochlorite, hydrogen peroxide, potassium permanganate, potassium dichromate (Turrer and Peres, 2010) and so on. These reagents are typically effective in depressing pyrite in chalcopyrite flotation. But the use of most inorganic depressants brings about negative effects, such as environmental hazards root in their toxicity and loss of precious metals from the mineral concentrates (Gül et al., 2008). Therefore, a significant undertaking of seeking clean, efficient and environmental friendly depressants is supposed to be solved.

Organic depressants of pyrite have been also studied extensively (Chen et al., 2011). Sodium humate (potassium humate) have been used to depress pyrite in the separation of sphalerite and pyrite with success. Liu and Xu (2005) reported that sodium humate exhibits forceful depression on pyrite in the flotation of galena from pyrite with little reaction on galena at specified conditions. Sodium humate molecule has two hydrophilic carboxyl groups and hence competitive adsorption occurs between xanthate and sodium humate on pyrite and the hydrophobicity of pyrite is reduced. Depression of pyrite flotation by dextrin has also been investigated by López Valdivieso et al. (2004), with their results suggesting the coadsorption of dextrin and collector on pyrite surface and the covered dextrin by dextrin results in pyrite depression. Polyacrylamide has also been studied as a depressant

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of pyrite when pyrite was separated from sphalerite in the presence of butylxanthate, with polyacrylamide strongly depressing pyrite flotation with little effect on sphalerite recovery (Boulton et al., 2001).

Sodium glycerine-xanthate (Fig. 1), as a new organic depressant, was synthesized only recently in 2006 (Xiong et al., 2006). After synthesis, they studied how the small molecular organic depressant affects the flotation of sulfide minerals. It was found that glycerine-xanthate has a strong effect on marmatite at $\text{pH} > 6.0$ and on arsenopyrite in weak acid with butyl-xanthate as collector. Furthermore, infrared spectrum showed competitive adsorption occurs between $-\text{OH}$ and $-\text{CSS}-$ in glycerine-xanthate molecule and butyl-xanthate on the mineral surface. He et al. (2007) demonstrated that glycerine-xanthate can also depress chalcopyrite flotation across a wide pH range.

The studies on the use of SGX as depressant are relatively rare, and the depression mechanism of SGX behind the experimental results on pyrite in chalcopyrite flotation is far from understood. In the presence of SGX, the flotation performance of pyrite and chalcopyrite and possible mechanism was discussed through flotation, adsorption and electrokinetic, FTIR reflection spectroscopic measurements.

2. Material and methods

2.1. Materials

Chalcopyrite and pyrite samples were supplied by Dahongshan copper mine, Yunnan Province and Tongling mine, Anhui province of china, respectively. The crystals were crushed and pulverized by a hammer and grounded in a procelain mill to get the particles. Then, the fine particles was screened using a sieve with a mesh aperture of $74 \mu\text{m}$ to get the $-74 \mu\text{m}$ fractions in undersize. Next, the $-74 \mu\text{m}$ size fractions was screened using a sieve with a mesh aperture of $38 \mu\text{m}$, the $-74 + 38 \mu\text{m}$ and $-38 \mu\text{m}$ size fractions was got in the oversize and undersize, respectively. Those two samples were used for the flotation tests and adsorption tests, respectively. The $-2 \mu\text{m}$ size fractions were prepared for electrokinetic potential studies. Both minerals were above 90% in purity (Table 1). X-ray diffraction measurements also showed these samples to be of high purity.

Sodium dibutyl dithiophosphate (SDTP) and Sodium butyl xanthate (SBX) of industrial grade from Tianjin Damao Chemical Reagent Factory were used as collectors. Sodium glycerine-xanthate was of analytical grade. The dextrin used in the work was supplied by HuBei Jing Jiang Flotation Reagents Co., Ltd. Its molecular weight was 56,000. KCl of analytical purity was used as background electrolyte solution. Pine oil was employed as a frother which was also industrial grade product. Analytical grade sodium hydroxide and hydrochloric acid were used for pH control.

2.2. Flotation tests

Flotation tests were carried out in a micro-flotation cell with an effective volume of 40 ml. For each test, mineral particles prepared

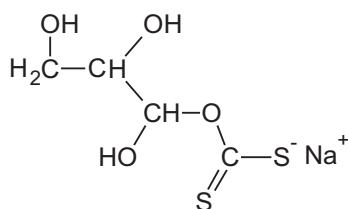


Fig. 1. The molecular structure of sodium glycerine-xanthate (SGX).

Table 1
Chemical analysis results of chalcopyrite and pyrite used in the experiments.

Element	Composition (%)	
	Chalcopyrite	Pyrite
Cu	35.14	0.17
Fe	27.47	44.26
Pb	0.009	0.021
Zn	0.019	0.002
S	32.39	49.71

(2.0 g) was placed in the cell after their surfaces were cleaned for 5 min using an ultrasonic cleaner to remove impurities, and then filled with 40 ml distilled water. After one minute of agitation, the pH value was adjusted to the target and then depressant, collector and frother were added successively. The conditioning time was 2 min, 3 min and 1 min, between each reagent addition, respectively. The flotation time was performed over 4 min. The floated and non-floated fractions were filtered, dried and weighed for the recovery calculation.

2.3. Electrokinetic potential measurements

A 0.1 g sample of pure mineral was first ground to $-2 \mu\text{m}$, and then transferred into a 100 ml breaker containing 50 ml solution of $1 \times 10^{-3} \text{ mol/L}$ KCl. The conditioning procedures listed in 2.2 for the flotation tests were conducted parallel with these electrokinetic potential measurements. The zeta-potentials were measured using a Malvern Zetasizer Nano ZS90 (England) equipped with a rectangular electrophoresis cell (DTS1060 Folded Capillary Cell). The conductivity and pH of the suspension were monitored continuously during the measurement and the environmental temperature was maintained at $25.0 \pm 0.5 \text{ }^\circ\text{C}$.

2.4. Adsorption tests

2.4.1. Adsorption of SBX

By using a ultra-violet (UV-3100) spectroscopy to measure the absorbance at wave length 301 nm (Woods et al., 1994), the absorbed amount of SBX onto chalcopyrite and pyrite, in the presence of SGX, was determined over the pH range 7 ± 0.5 . A 2.0 g sample of $-38 \mu\text{m}$ sized pure mineral was pulped with 40 ml distilled water, and then the solution was stirred for 15 min followed by centrifugation at 4500 rpm for 10 min using a high speed refrigerated centrifuge while a known amount of desired reagents was added. The suspensions were then filtered and finally the treated solution was measured with the UV spectrometer. The adsorbed amount of SBX on mineral was calculated from the difference in the concentration of initial and residual SBX in the solution.

2.4.2. Adsorption of SGX

The adsorbed amount of SGX (He et al., 2011) on chalcopyrite and pyrite was measured in a glass vessel at $25 \text{ }^\circ\text{C}$. Firstly, a known concentration of SGX stock solution was mixed into the vessel after a 5.0 g sample being firstly conditioned for 5 min in KCl solution, and continuously stirred until adsorption equilibrium reached 60 min. A sample was obtained from the solution to reveal the concentration of SGX remaining in the solution. Another concentration of SGX solution was added to the suspension and conditioned for a further 60 min. The extracted samples were centrifuged twice. Next the concentration of SGX remaining in the solution was determined by using colorimetric techniques. The amount of SGX in the solution was measured using the Dubois method (Dubois et al., 1956), based on phenol-sulfuric acid reaction for the determination of sugars. Firstly, 100 mg SGX was dissolved in a 100 mL

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