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Study on the flotation technology and adsorption mechanism of galena–jamesonite separation

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A B S T R A C T

In order to further separate the concentrate containing galena and jamesonite before undergoing hydrometallurgical process, flotation experiment was performed on the basis of mineralogical analysis. And the adsorption mechanisms of collector H on galena and jamesonite were also studied by FT-IR spectra analysis and molecular dynamics (MD) simulation. The flotation result shows that the efficient separation can be achieved with H as selective collector. Galena concentrated with Pb grade of 72.09% and Pb recovery of 50.96% was obtained, and jamesonite concentrated with Sb grade and recovery of 10.89% and 76.67% respectively was obtained as well. Infrared spectrum analysis indicates that collector H can adsorb on the surface of galena and react with Pb^{2+} to generate hydrophobic salt, while no evident adsorption phenomenon was observed on the surface of jamesonite. The MD simulation and calculation results demonstrate that adsorption energy of collector H on galena and jamesonite surface is −872.74 kJ/mol and −500.538 kJ/mol, respectively, which means collector H is easier to adsorb on the surface of galena than that of jamesonite.

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1. Introduction

The reality of conservation-minded and environment-friendly society poses a big challenge on the beneficiation and smelting industry, which makes exploration of novel and efficient separation technology a necessity. As a unique kind of sulfosalt mineral in China, jamesonite ($Pb_4FeSb_6S_{14}$) is an important source of Sb and Pb and is used to associate with galena, marmatite and pyrrhotite [1–3]. Commonly, the concentrate produced through conventional beneficiation technology containing jamesonite and galena is directly sent to smelting plant to be separated through hydrometallurgical process, which results in high energy consumption and high cost. Though novel flotation technologies have been widely developed [4,5], there are hardly any papers about the separation of jamesonite and galena [6–10].

In mineral processing field, only macroscopical, unilateral and qualitative analysis can be achieved through regular mechanism analysis method and they have a strict requirement on the purity of the minerals and test operations. Besides, it is impossible for quantum chemistry, which only is applied to simple system of single election, to be used to simulate and analyze complex system. In comparison, molecular dynamic simulation is a powerful method and has a big application potential in researching the function mechanism between the reagents and minerals. Neglecting the effect of electrons, adopting experiential and parameterized force fields and considering dynamic characteristics of the whole system, molecular dynamic simulation enables us to study the adsorption structure and dynamic process in a molecular level [11–18].

In this paper, novel flotation separation technology of galena and jamesonite was determined on the basis of roughing condition experiments and closed-circuit test. Then FT-IR spectra analysis and molecular dynamic simulation were further conducted to explore the adsorption mechanism of collector H on galena and jamesonite.

2. Materials and methods

2.1. Materials and characterization

The concentrate containing jamesonite and galena in the flotation test were obtained from Tibet, China. Chemical composition analysis was carried out by X-ray fluorescence spectrometry (XRF) technique by using a Philips spectrometer. Phase composition of the ore was investigated by Powder X-ray diffraction (XRD). Beneficiation reagents used in this study are listed in Table 1.

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2.2. Flotation test

Flotation separation test was conducted in a 1.5 L flotation cell with a spindle speed of 2400 r/min and pulp concentration of 25% (mass fraction) at room temperature. Differential flotation technology was adopted and the flotation condition test flowsheet was shown in Fig. 1. Reagents used and their function are listed in Table 1.

2.3. FT-IR spectra analysis

As a widely used method in studying the interaction mechanism between reagents and minerals, FT-IR spectra analysis was performed through a Nicolet NEXUS-470 spectrometer to study the interaction between collector H and minerals. The pure galena and jamesonite minerals gained from Tibet were ground to be less than 5 μm in an agate mortar before mixed with collectors. Then 1.0 g mineral sample containing given collectors was added into a 50 mL beaker at pH 12 to be mixed with analytical sodium hydroxide. And then the mixed sample was stirred magnetically for 10 min, followed by filtrating and rinsing for 2 or 3 times with corresponding pH buffer solution. After that, the sample was dried in a vacuum desiccator at room temperature, and then used for FTIR reflection spectra measurement.

2.4. Molecular dynamic simulation and calculation

In order to further explore the adsorption mechanism of collector H on jamesonite and galena, MD simulation and adsorption energy calculation were conducted by using Material Studio 6.0 program. During the process, Cambridge Serial Total Energy Package (CASTEP) module was adopted in the geometry optimization of galena and jamesonite crystal structures. Optimization of collector structure was performed in the DMol3 module. The simulation and calculation process were carried out in the experiential and parameterized universal force field of the Forcite module.

The adsorption energies between collector H and minerals were characterized by ΔE value. When the adsorption energy $\Delta E > 0$, it suggests that the collector can hardly adsorb on the mineral surface; when adsorption energy $\Delta E < 0$, it shows that the total system energy decreases after collector adsorbed on surface, and the more negative ΔE is, the stronger the interaction between collector molecule and mineral surface will be [19].

3. Results and discussion

3.1. Mineralogical characteristics

XRF and XRD results of the experiment sample are shown in Table 2 and Fig. 2 respectively.

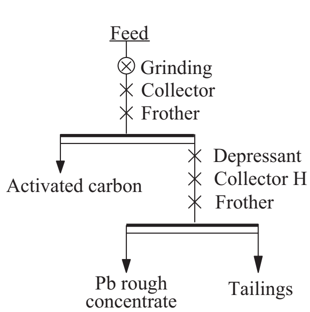

Fig. 1. Flowsheet of flotation condition test.

Table 1
Reagents used in the flotation test.

Reagents	Function
Lime	pH regulator
Kerosene	Activated carbon collector
Sodium sulfide	Regulator
Activated carbon	Regulator
Calcium hypochlorite	Dispersant
H	Galena collector
Ammonium dibutyl dithiophosphate	Jamesonite collector
Terpenic oil	Frother

Table 2
Chemical composition of the ore sample (mass fraction, %).

Composition	Pb	Sb	Cu	Fe	S	O
Grade	43.15	5.90	0.67	11.61	17.04	13.82

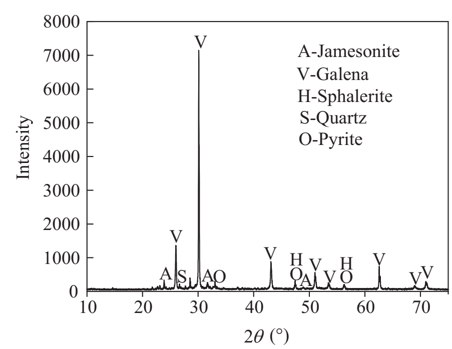

Fig. 2. X-ray diffraction pattern of the galena–jamesonite mixed concentrate.

Table 1 suggests that the main valuable elements in the concentrate are Pb and Sb with a grade of 43.15% and 5.90% respectively. And the XRD result indicates that Pb and Sb mainly exist in the form of galena and jamesonite, and Quartz and pyrite are the dominate gangue minerals, as shown in Fig. 2.

3.2. Flotation studies

Flotation condition test is an important process to determine the optimum experiment parameters. Through the condition experiment, grinding time was determined as 5 min, and the dosages of sodium sulfide and activated carbon added during the grinding process to remove the residual reagents are 1 kg/t and 2 kg/t respectively. The optimum usage of collector kerosene adopted to get rid of the activated carbon was 5 g/t and 30 g/t of the frothy terpenic oil. Calcium hypochlorite and lime with a dosage of 500 g/t and 40 kg/t respectively were chosen as the combined depressants for jamesonite, and the optimum usage for collector H is 100 g/t. Finally, rough concentrate of galena with Pb grade of 68.25%, Pb recovery of 47.71%, Sb grade of 1.26% and Sb recovery of 6.47% was obtained.

Based on the condition test, closed circuit flotation separation experiment was conducted in accordance with the flotation technology given in Fig. 3. And the separation result is shown in Table 3.

According to Table 3, galena concentrated with Pb grade of 72.09% and Pb recovery of 50.96% was gained. The jamesonite concentrated with Sb grade and recovery of 10.89% and 76.67% respectively was obtained. Though there are still certain content of Pb and Sb (8.17% and 2.15% respectively) existing in the tailing, separating jamesonite and galena through the technology can largely decrease the smelting cost and energy consumption.

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