Flotation Study of an Oxy-sulfur Mixed Copper Ore
Presented Feldspar Quartz Sandstone-type

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Abstract. The technological mineralogy and benefication research of an oxy-sulfur mixed copper ore were carried out. The test contents included: grinding fineness, collector dosage for sulphur ore, activator dosage and collector dosage for oxidized ore, open circuit and closed circuit test, etc. The results showed that under the grinding fineness -0.074 mm of 70%, the copper concentrate with a yield of 5.46%, a copper grade of 18.14% and a recovery rate of 68.31% was obtained through the preferred flotation process. The process was one roughing, two cleaning and two scavenging for sulphide ore, one roughing, three cleaning and three scavenging for oxidized ore. The silver content in the copper concentrate was 438 g/t, and copper content in the tailings was 0.486%. The dosage of agent in whole process were 500 g/t lime, 1500 g/t sodium sulfide, 1500 g/t SW, 827.5 g/t isoamyl xanthate, 207.5 g/t ammonium dibutyl dithiophosphate, and 260 g/t 2# oil.

1. Preface
Copper resources of China rank the seventh in the world, of which copper oxide accounts for about a quarter, with more than 10 million tons of metal reserves. Copper resources of China are mainly distributed in the west, such as Tibet, Xinjiang, Yunnan, etc., which have huge reserves of copper mineral resources [1], while the silver element is commonly associated in copper deposits [2]. A copper ore are primary composed of sulphide ore and oxidized ore, containing a small amount of silver which is difficult to separated. There are many methods of separate oxy-sulfur mixed copper ore at home and abroad, including sulphide flotation, fatty acid flotation, amine flotation and chemical dressing [3-5]. The object of this paper is to study the technological mineralogy of the copper mine and the separation test.

2. Ore properties

2.1 Multielement analysis and phase analysis of raw ore
The results of chemical multielement analysis of raw ore were shown in table 1, and the results of copper phase analysis were shown in table 2.

It can be seen in table 1 and 2 that the ore has a high copper grade and a certain amount of silver, while silver can be used in copper concentrate. Copper phase mainly consists of free copper oxide and secondary copper sulfide, with a total of 90.07% and oxidation rate of ore is 56.51%.
Table 1. Chemical analysis results of raw ore (%).

| Items          | Cu  | S    | TFe  | Au*  | Ag*  |
|----------------|-----|------|------|------|------|
| Contents       | 1.45| 0.30 | 1.69 | <0.2 | 40.57|

| Items          | TiO₂ | SiO₂ | Al₂O₃ | MgO | CaO |
|----------------|------|------|-------|-----|-----|
| Contents       | 0.49 | 67.78| 8.52  | 1.40| 5.48|

*Unit: g/t, follow as the same.

Table 2. Analysis results of copper phase (%).

| Phase          | Copper sulfide | Copper oxide | Other | Total |
|----------------|----------------|--------------|-------|-------|
|                | Primary        | Secondary    | Free  | Bonded|      |
| Contents       | 0.012          | 0.487        | 0.820 | <0.01 | 0.132 |
| Distribution   | 0.83           | 33.56        | 56.51 | <0.69 | 9.10  |

2.2 Ore composition
The identified samples were obtained from the ore dressing samples, and they were grinded to thin and light sheets to be identified. The samples are gray-dark gray, with green copper oxides on the surface and blisters on the surface dripping with 5% hydrochloric acid. The mineral compositions and contents were shown in table 3.

It can be seen from table 3 that the rock has a fine-grained sand-like structure, which is mainly composed of quartz, feldspar and interstitial of calcite, chalcocite and carbonaceous. The copper mineral is mainly chalcocite, followed by malachite and a small amount of copper blue, which presented dependent grain structure, sparse disseminated structure, veins structure.

Table 3. Mineral composition and content.

| Minerals              | Contents | Minerals            | Contents |
|-----------------------|----------|---------------------|----------|
| Chalcoite             | 5%       | Muscovite           | A little |
| Copper blue           | Traces   | Biotite             | A little |
| Malachite pulse       | A little | Siliceous rock      | A little |
| Malachite irregular   | A little | Mudstone            | A little |
| aggregate             |          | Quartz              | 70~75%   |
|                       |          | Clay minerals, sericite | A little |
| Plagioclase,          | 5~10%    | Carbon              | A little |
| Potassium feldspar    |          | Calcite             | 10~15%   |

3. Experimental results and discussions
This copper ore is mainly composed of chalcocite and malachite, which sulfide ore accounting for 34.39% and oxidized ore accounting for 56.51%. In view of the characteristics of the ore above, the preferential flotation scheme of first sulfur and then oxygen was adopted for the test.

3.1 Grinding fineness test
The grinding fineness test process and the agent conditions were shown in figure 1 and the test results were shown in figure 2.
Figure 1. Flowchart of grinding fineness test.

Figure 2. Results of grinding fineness test.

Figure 2 illustrates that with the increase of grinding fineness, copper grade gradually decrease, and the recovery rate increase first and then decrease. When grinding fineness of -0.074mm is 70.1%, copper grade in concentrate is 9.03% and recovery is 67.20%. The copper grade and recovery rate in concentrate change little with increase the grinding fineness. The grinding fineness of the subsequent test was determined as 70.1% of -0.074mm in view of grinding costs.

3.2 Collector dosage test of sulfide ore
Under the grinding fineness of 70.1% -0.074mm, the dosage test of copper sulfide flotation collector was conducted according to the process in figure 1, the test conditions were that 60+50 g/t 2# oil was used as the foaming agent, and variable the dosages of the combination of isoamyl xanthate and ammonium butyl aerofloat was used as the roughing and scavenging collector, and the test results were shown in figure 3.
Figure 3. Results of collector dosage copper in sulfide flotation.

It can be seen from figure 3 that with the increase of collector dosage, the concentrate copper grade gradually decrease, and the recovery rate increase first and then decrease. The dosage of isomyl xanthate sulfide collector was determined to 250 g/t in the roughing, 125 g/t in the scavenging, and the dosage of ammonium butyl aerofloat was determined to 62.5 g/t in the roughing, and 31.3 g/t in the scavenging after comprehensive consideration.

3.3 Flotation condition test of oxidized ore

3.3.1 Activator dosage test

The test process of sodium sulfide dosage for the copper oxide was shown in figure 4. Flotation condition of copper oxide: variable sodium sulfide, 1000+500 g/t SW, 250+125 g/t isoamyl xanthate, 62.5+31.3 g/t ammonium butyl aerofloat. The flotation results were shown in figure 5.

Figure 4. Flowchart of flotation condition test for copper oxide.
It can be seen from figure 5 that with the increase of sodium sulfide dosage, the grade and recovery rise first and then drop. The trend indicated that the sodium sulfide was less effective with a little dosage and had inhibitory effect on copper oxide with more dosages. The sodium sulfide dosage was determined to 1000 g/t in the roughing and 500 g/t in the scavenging by comprehensive consideration. The test process of sodium sulfide dosage for the copper oxide was shown in figure 4. Flotation condition of copper oxide: 1000+500 g/t sodium sulfide, variable SW, 250+125 g/t isoamyl xanthate, 62.5+31.3 g/t ammonium butyl aerofoam. The flotation results were shown in figure 6.

It can be seen from figure 6 that with the increase of dosage of SW as activator, the grade and recovery rate of concentrate 2 rise first and then fall, which indicated that the activation effect was poor with a little of SW, and the inhibitory effect for copper oxide was strong with a lot of SW. The activator SW dosage was determined to 1000 g/t in the roughing and 500 g/t in the scavenging by comprehensive consideration.

3.3.2 Collector dosage test
The test process of collector dosage for the copper oxide was shown in figure 4. Flotation condition of copper oxide: 1000+500 g/t sodium sulfide, 1000+500 g/t SW, variable isoamyl xanthate, variable ammonium butyl aerofoam. The flotation results were shown in figure 7.
Figure 7. Results of collector dosage.

It can be seen from figure 7 that with the increase of collector dosage, the grade of concentrate 2 rise first and then fall, the recovery rate of concentrate 2 was on the rise. The collector isoamyl xanthate and ammonium butyl aerofloat dosage were determined to 250 g/t, 62.5 g/t in the roughing and 125 g/t, 31.3 g/t in the scavenging by comprehensive consideration.

3.4 Closed-circuit test
The closed-circuit test was carried out according to the process and agent conditions shown in figure 8. A total of 6 cycles were made which the concentrate and tailings were balanced by the third cycle, and the test results were shown in table 4.
Figure 8. Flowchart of close-circuit.

Table 4. Results of close-circuit (%).

| Items               | Yield | Grade | Recovery |          |
|---------------------|-------|-------|----------|----------|
|                     |       | Cu    | Ag*      | Cu       | Ag       |
| Concentrate 1       | 3.98  | 21.15 | 497      | 58.05    | 48.76    |
| Concentrate 2       | 1.48  | 10.05 | 279      | 10.26    | 10.18    |
| Concentrate 1+2     | 5.46  | 18.14 | 438      | 68.31    | 58.94    |
| Tailings            | 94.54 | 1.48  | 40.57    | 31.69    | 41.06    |
| Raw ore             | 100.00| 1.45  | 40.57    | 100.00   | 100.00   |

Table 4 illustrates that the yield, copper grade, copper recovery, silver grade and silver recovery of combined copper concentrate of oxy-sulfide is 5.46%, 18.14%, 68.31%, 438g/t, 58.94%, and the copper grade of tailings is 0.486%.
4. Conclusions

(1) The ore contains a higher copper grade and a certain amount of silver, of which copper phase mainly consists of free cupric oxide and secondary cupric sulfide, with a total of 90.07% and an ore oxidation rate of 56.51%, belonging to mixed copper ore of oxygen-sulfur. Grinding fineness -0.074 mm of 70% was the best grinding fineness.

(2) The copper concentrate with a yield of 5.46%, a copper grade of 18.14%, a recovery rate of 68.31%, a silver grade of 438 g/t was obtained through the preferential flotation test of copper sulfide with 500 g/t lime, 1500 g/t sodium sulfide, 1500 g/t SW, 827.5 g/t isoamyl xanthate, 207.5 g/t ammonium butyl aerofloa, and 260 g/t 2# oil, while the copper grade in the tailings was 0.486%. Although the flotation process of copper sulfide was more complicated and the dosage of agent was higher, the mineral processing index was ideal, the operation was convenient and the production index was stable.

(3) The grade of tailings was still high (0.486%) that the development and utilization of it should be further studied.

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