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# The effect of a novel depressant on the separation of talc and copper – nickel sulfide ore

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**Abstract:** This paper researched the influence of the polysaccharide polymer sodium alginate (SAG) on the depression of talc at a fixed room temperature about 25 °C through micro flotation and batch flotation experiments, zeta potential and contact angle measurements as well as infrared spectroscopy analysis. The flotation results displayed that the SAG had a significant influence on the flotation of talc but less influence on sulphide flotation. Compared with the depressant carboxymethyl cellulose (CMC) and guar gum, using of the SAG gave the highest copper recovery. It could not only eliminate a talc removal step, but also significantly decrease in the depressant consumption by half at least. Sodium alginate apparently adsorbs on the talc surface and promotes hydrophilization, as revealed by contact angle tests (contact angle decreased from 75 to 33° after treating with SAG). It is demonstrated that the SAG obviously absorbed at the surface of talc but rarely for chalcopyrite through the results of zeta potential measurements and infrared spectroscopy analysis.

**Keywords:** Sodium alginate, talc, copper –nickel sulfide, polysaccharide depressant, flotation

## 1. Introduction

Talc is a layered hydrous magnesium silicate in which the layers are held together by van der Waals bonds. During grinding, two different surfaces are formed. Basal cleavage planes are formed by rupture of van der Waals bonds. Because the resulting planes contain no broken Si–O and Mg–O bonds, the surface is neutral and hydrophobic. However, the edges of the mineral sheets contain broken Si–O and Mg–O bonds and, consequently, charged species and the edges thus exhibit hydrophilic properties (Wang et al., 2005). Talc is the most common hydrophobic mineral encountered in complex sulphide ore and in the ore of platinum group metals (Engel et al., 1997; Pietrobon et al., 1997; Cawood et al., 2005; Bremmell et al., 2005; Beattie et al., 2006a; Wiese et al., 2007). The presence of hydrophobic gangue represents a primary problem in flotation of both copper and copper–nickel sulphide ore. Being naturally hydrophobic, in copper sulphide processing, talc is easily reported to flotation concentrates, thus reducing concentrate grade and causing downstream processing problems as well as increased smelting costs (Beattie et al., 2006b; Feng et al., 2012a; Zhao et al., 2015). Sequentially, the separation of talc and other magnesia-bearing minerals from various sulphide ore has been the focus of plentiful researches.

Adding depressants is a common method in selective flotation of copper minerals from ore. So, various sort of polysaccharides and their derivatives have been widely used in the minerals flotation to depress hydrophobic gangue minerals such as talc for several decades (Bakinov et al., 1964; Pugh et al., 1989a). A great deal of studies (Pugh et al., 1989a, Morris 1996; Shortridge et al., 2000; Morris et al., 2002; Liu et al., 2002; Parolis et al., 2004) on the application of polymer, like carboxymethyl cellulose, guar gum and other polysaccharide polymers, as a depressant for magnesia-bearing minerals present in various sulphide ore. Meanwhile, guar gum has been one of the most widely used depressant for

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magnesia-bearing gangue minerals (Healy et al., 1974; Mackenzie et al., 1986; Pugh et al., 1989a; Rath et al., 1997a; Rath et al., 1997b). However, this tends to force guar gum pricing to be market related due to the limited availability and high cost (Jiang et al., 2012; Zhao et al., 2015). Therefore, it is crying needs to develop other polymer depressants with stronger selective and lower price except for high performance for separation of sulphide (like copper) from magnesia-bearing minerals.

Currently, many new effective polymer depressants have been widespread application into the minerals processing. Besides, the research in this aspect is also being updated continually. The term alginate refers to a family of polyanionic copolymers derived from brown sea algae and comprises 1,4-linked β-D-mannuronic (M) and α-L-guluronic (G) residues in varying proportions (Matthew et al., 1995; Lindenhayn et al., 1999; Ishikawa et al., 1999). Sodium alginate is soluble in aqueous solutions and forms stable gels at room temperature in the presence of non-cytotoxic concentrations of certain divalent cations (i.e., $Ba^{2+}$, $Ca^{2+}$, $Mg^{2+}$ ) through the ionic interaction between the guluronic acid group (Wang et al., 2003). Sodium alginate (SAG) is a new high molecular weight polysaccharide, mostly used as a powerful water-soluble dietary fiber supplement in food additives, medicine, chemicals, etc. (Huang et al., 1999; Kulkarni et al., 2000; Wasikiewicz et al., 2005). Seaweed plants grow in oceans and lakes (Crouch et al., 1993; Khan et al., 2009). SAG have the advantage of wide source and cheap price compared with guar gum. Using SAG as a commercial depressant for the flotation separation of copper –nickel minerals from Cu/Ni sulfide ore has not been reported, and the theoretical investigation on the adsorption mechanism between depressant SAG and minerals has not been studied previously.

In this research, the sodium alginate (SAG) was developed as a depressant by the authors to depress talc effectively, and the depressing performance of SAG was compared with guar gum and carboxymethyl cellulose (CMC) in the flotation of copper–nickel minerals from a low-grade Cu/Ni sulfide ore which contains talc, in the Tianlong Copper–nickel Mine. In addition, the adsorption mechanisms of SAG on chalcopyrite and talc were investigated by contact angle tests and zeta potential measurements as well as infrared spectrum analysis.

## 2. Materials and methods

### 2.1. Samples and reagents

#### *2.1.1. Samples*

Pure mineral samples of chalcopyrite and talc were obtained from the Tianlong Copper–nickel Mine, Xinjiang Autonomous Region, China. After being handpicked, crushed, ground and screened, the powder samples of −75 + 38 μm fractions were used in flotation tests. The chemical composition and X-ray diffractometry (PANalytical B.V., Almelo, The Netherlands) of chalcopyrite and talc that were used to study the chemical characteristics and mineral compositions are shown in Table 1 and Figure 1. The chemical analysis results show that the purity of as-prepared chalcopyrite and talc is 95.8% and 97.2%, respectively. Low-grade Cu/Ni sulfide ore (containing talc) for batch flotation tests was from the Tianlong Copper–nickel Mine. Multi-elemental chemical analysis of the ore was conducted by Atomic Adsorption Spectroscopy (AAS) and Inductively Coupled Plasma Optical Emission Spectrometer (ICP-OES), and the analysis results are shown in Table 1. As shown in Table 1, minerals contained 0.27% Cu, 0.53% Ni, 16.63% MgO, 41.19% $SiO_2$ and 8.21% $Al_2O_3$, and also contained many platinum group metal. The mineralogical data confirmed that in this Cu/Ni sulphide ore, copper mainly existed in the form of chalcopyrite.

#### *2.1.2. Reagents*

The depressant sodium alginate [SAG, MW 32000~200000, the viscosity of solutions of 1% SAG (by weight) is 1,000～1,500 mPa·s] was supplied independently by the IMUMR Flotation Reagents Limited Company. SAG solutions were prepared by dispersing a known weight of SAG (the molecular formula of the SAG is $(C_6H_5O_6)m \cdot (C_{12}H_{10}O_9)_n$, >92% purity) in distilled water. The solution was made up to the required volume by adding distill water and left to equilibrate overnight. Fresh solutions were prepared every 3 days. In the micro flotation tests, SAG was used as depressant, Potassium Amyl Xanthate (PAX) was used as collector, methyl iso-butyl carbinol (MIBC) was used as frother, and hydrochloric acid (HCl) and sodium hydroxide (NaOH) were used as pH regulators. All reagents used in micro flotation tests were of analytical grade. Deionized double distilled water was used for micro flotation, contact angle and zeta-potential as well as infrared spectra experiments. In batch flotation tests, SAG, guar gum, carboxymethyl cellulose (CMC), were used as a depressant, oxalic acid was used as pH regulators. PAX (a sulphide collector was used as collector. And MIBC was used as frother. All reagents (except SAG) used in batch flotation were of industrial grade. Tap water was used for batch flotation tests.

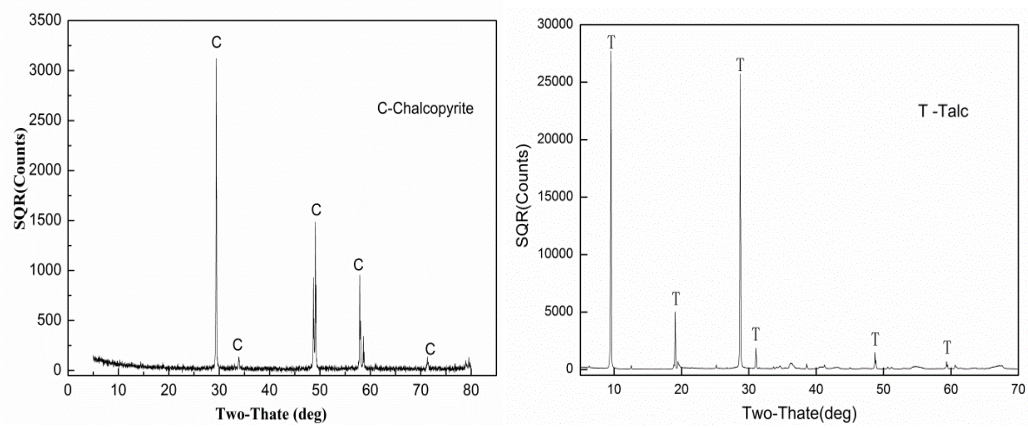


Fig.1. XRD spectrums of pure (a) chalcopyrite and (b) Talc for flotation tests

Table 1. The results of multi-elemental chemical analysis of the ore for batch flotation and industrial tests

| Element | Cu(%) | Ni(%) | S(%) | TFe(%) | MgO(%) | $SiO_2$(%) | $Al_2O_3$(%) | Ag (g/Mg) | Pt (g/Mg) |
|---|---|---|---|---|---|---|---|---|---|
| Grade | 0.27 | 0.53 | 4.88 | 9.95 | 16.63 | 41.19 | 8.21 | 4.78 | 0.24 |

### 2.2. Experiments

#### *2.2.1. Micro flotation tests*

Micro flotation experiments were proceeded in a flotation machine of XFG-1600 type (mechanical agitation) with the volume of 40 $cm^3$.The impeller speed was fixed at 1900 rpm. It should be noted that the room temperature was fixed at 25 ± 1 ℃ during the experiments. The mineral suspension was prepared by adding 2.0g of single mineral to 40 $cm^3$ of solutions in single mineral flotation tests, and adding 1.0g each of chalcopyrite and talc to 40 $cm^3$ of solutions in mixed minerals flotation. The mineral surfaces were cleaned by using ultrasound cleaner. The pH of the mineral suspension was adjusted to the desired operating value by adding HCl or NaOH stock solutions.

Scheme involved adding depressant, collector and frother with each stage having a 2 min conditioning periods prior to the next reagent addition. Flotation concentrates were then collected for a total of 5 min. The floated and unfloated particles were collected, filtered and dried. In single mineral flotation, the recovery was calculated based on solid weight distributions between the two products. In mixed minerals flotation, the flotation recovery was assessed by chemical analysis of the two products. In order to assess the accuracy of flotation tests, the errors of the recovery were found to be within 1.0% after at least five tests on each condition, and the average values were reported.

#### *2.2.2. Batch flotation tests*

The ore (1 kg) was crushed to -3 mm and then ground to 73% passing 74 μm in a closed steel XMQ-240 × 90mm ball mill at a pulp density of 65% by weight. The bench-scale flotation tests were performed in XFD-63 flotation cell (self-aeration), 3000 $cm^3$ for rougher flotation and 1000 $cm^3$ for cleaner flotation, and 500 $cm^3$ for flotation separation of copper/nickel minerals, respectively. The Cu/Ni bulk flotation used 1kg ore to obtain a Cu/Ni bulk concentrates. After wet grinding, the desired amounts of reagents were added to the slurry while agitating at about 1900 rpm and the slurry was conditioned for 6 min. During the batch flotation tests, the room temperature still keep constant at 25 ± 1 ℃. Air was then fed and the froth flotation was continued for 5 min during which a rougher concentrate was collected. The rougher concentrates and tailings were filtered, dried, weighted, sampled and assayed for copper and nickel. To assess the accuracy of flotation experiments, the calculated grade of feeding was compared with the head assay. If the calculated copper grade of feed was not in the range of 0.27 ± 0.01%, then the concentrates and tailings were re-assayed for copper, or the flotation tests were redone. The flotation flow sheet of the bench-scale tests is described in Fig. 2. The experimental system used SAG as depressant (the total dosage of SAG in locked cycle test was 597 g/Mg), and the comparative system used guar gum and CMC as depressant (the total dosage of guar gum and CMC in closed cycle test was about 950 g/Mg and 1200 g/Mg, respectively). All of the samples were thoroughly equilibrated, and an average recovery and grade of at least three individual experiments was recorded.

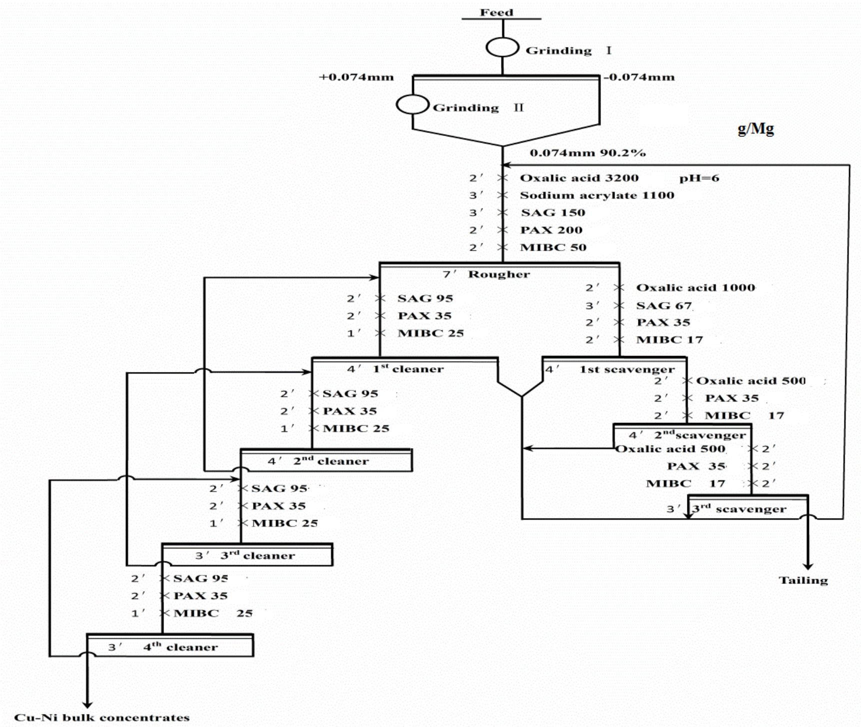


Fig. 2. The flow sheet of closed cycle tests

### *2.2.3. Sedimentation experiment*

The turbidity of talc was measured by a ULTRATURB plus instrument provided by Hach Ltd., American. 25mg single minerals with corresponding reagent (analytical grade) solution were used for each test. The mixture suspension (100cm$^3$) was agitated for 10 min with magnetic stirrer. The pulp was transferred to the 100 cm$^3$ settling tube and turned upside-down for 10 times. The settling tube was static for 5min and then extracted a suspension 30 cm$^3$ as the experimental samples. The turbidity measurement results were recorded for each 0.5 min, and a total of 3 min was measured. The measurement error was found to be within 2.0% after at least five measurements at each condition, and the average values were reported.

### *2.2.4. Contact angle tests*

Static contact angles of the probe liquids on the sample surfaces were measured using GBX contact angle meter (France) equipped with a digital camera and computer software for the contact angle calculation from the shape of the settled droplet. The surface of the bulk mineral was cut and polished before the treatment with the reagents like SAG (pH=6), in order to minimize the effect of surface defects on the experiments (Gao et al., 2012；Gao et al., 2013). Polishing operation was carried out in the equipment P20903 (as shown in Fig. 3) provided by Qingfeng Ltd, China. A liquid drop of about 3.5 × 10$^{-3}$cm$^3$ was placed on the sample surface, and the reading of contact angles was taken automatically on the left and right sides of the water droplet profile by computer software. The measurements of the contact angles were conducted at room temperature of 25 ± 1 ℃. At least 3 contact angle measurements were taken for each probe liquid on each sample surface.

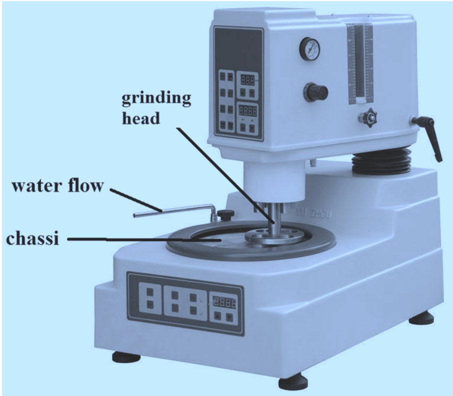


Fig. 3. Polishing equipment in contact angle tests

*2.2.5. Zeta-potential measurements*

Zeta potential experiments were conducted using a Coulter DELSA440S II Type electro-kinetic instrument with electrolyte solution of 0.01 mol/dm$^3$ KCl. 20mg single minerals with corresponding reagent (analytical grade) solution were used for each test. The mixture suspension was agitated for 10 min with magnetic stirrer. The pH of the mineral suspension was adjusted to the desired operating value by adding dilute either HCl or NaOH solutions. In each case, the average of three independent measurement with a typical variation of 5 mV was reported.

*2.2.6. Infrared spectrum measurements*

One gram of -45 μm chalcopyrite or talc sample was ground to about -2 μm in an agate mortar, then placed into 50 cm$^3$ aqueous solution with or without 25 mg/dm$^3$ depressant at pH 6, and conditioned for 0.5 h. After that, the samples were filtered, three times washed with distilled water, and dried in a vacuum oven at room temperature (25 ± 1 ℃) for 24 h. The Fourier transform infrared (FTIR) spectra of samples were recorded by a Bruker Alpha (Thermo, USA)FT-IR spectrometer in the range from 400 cm$^{-1}$ to 4000 cm$^{-1}$ as KBr pellets.

## 3. Results and discussion

### 3.1. Micro flotation tests

*3.1.1. Effects of different depressants*

Many researchers indicated that the pure talc was floatable over a wide pH range, and the talc recovery could reach more than 90% by adding frother only (Zhao et al., 2015). It can be inferred that it may be difficult to separate nickel–copper minerals from Cu/Ni sulfide ore in the absence of depressant. Fig. 4. shows the effects of different depressants on the floatability of talc. The results in Fig. 4. demonstrated that compared with guar gum and CMC, the floatability of talc became weaker after adding the SAG depressant. The pH value of 6.0 was chosen to conduct following conditional experiments. After the addition of polysaccharide depressants, the turbidity of the upper suspension was increased after precipitation. Which was meant that the dispersity of talc in the pulp was decreased, especially for CMC and guar gum compared with SAG. It is generally believed that strengthening the dispersion of the gangue minerals in the pulp can reduce the probability of being floated by the foam entrainment, which is beneficial to the depression of gangue (Harris et al., 1983; Liu et al., 2012). However, according to the turbidity test results, in combination with the flotation recovery rate and dispersion of talc can be seen that the aggregation of the particles may be more conducive to its inhibition. Sodium alginate was beneficial to the flocculation of talc, which probably was one of the most important reasons for the stronger suppressed ability to talc than CMC and guar gum.

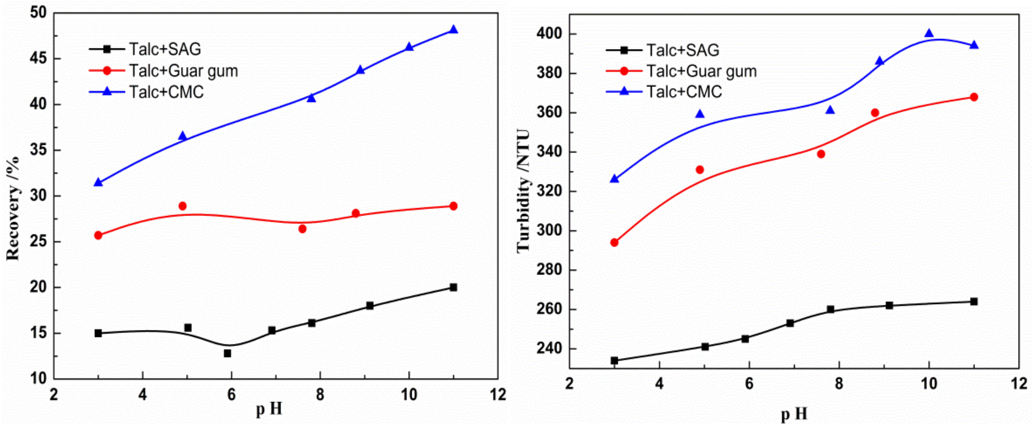


Fig. 4. The effects of different depressants on (a) the flotation recovery of talc (8 mg/dm$^3$ MIBC) and (b) the turbidity of the suspension liquid as a function of pH (temperature at 25 ± 1 ℃)

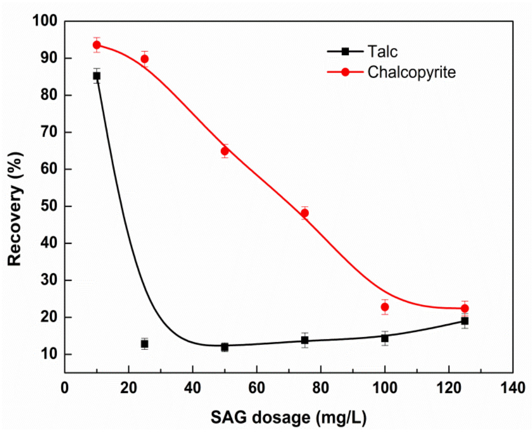


Fig. 5. The effect of SAG dosage on the flotation recovery of single minerals (pH 6, [PAX] = 0.24 mmol/dm$^3$, [MIBC] = 8 mg/dm$^3$, temperature at 25 ± 1 ℃)

### *3.1.2. Effect of SAG dosage*

Fig. 5. presents the effect of SAG dosage on the flotation recovery of chalcopyrite and talc at pH 6. It is evident from the figure that chalcopyrite and talc had good floatability by using PAX as collector and MIBC as frother. Fig. 5. also indicated that SAG had little depression effect on chalcopyrite, while the talc recovery decreased dramatically with an increase in SAG concentration. In the presence of 25 mg/dm$^3$ SAG, the flotation recovery of talc was about 15%, and recovery of chalcopyrite was over 89%. The results demonstrated selective depression effect of SAG on talc.

### *3.1.3. Mineral mixture flotation*

On the basis of single mineral flotation tests (temperature at 25 ± 1 ℃), the selective flotation tests of mixed minerals were conducted under the condition of pH 6, PAX 0.24 mmol/dm$^3$, MIBC 8 mg/dm$^3$, and the flotation concentrates were collected for 1, 2, 3, 4 and 5 min, respectively. The effects of flotation time on the recovery of Cu and MgO in copper concentrate with and without SAG are shown in Fig. 6., and the separation result after 5 min is listed in Table 2. It is evident from the results in Fig. 6. that without SAG, the recovery of MgO (talc) in Cu concentrates rose dramatically when the flotation time increased. The results in Table 2 indicated that SAG could separate chalcopyrite effectively from the mixed minerals with the recovery of copper in Cu concentrates up to 94.0% as well as the recovery and grade of MgO down to 8.8%, 2.37%, respectively.

According to the results of micro flotation tests, it can be inferred that the flotation separation of copper–nickel minerals from a Cu/Ni sulfide ore which contains talc was possible with SAG as depressant.

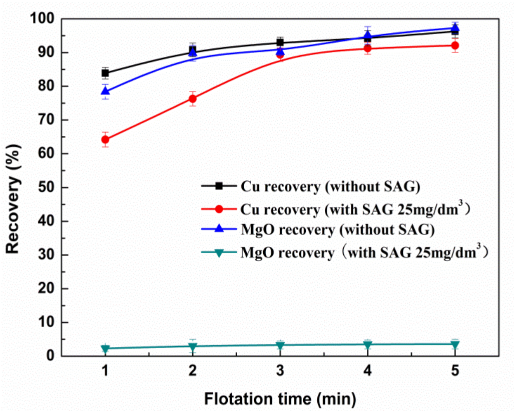


Fig. 6. The effect of flotation times on the recovery of Cu and MgO (talc) in Cu concentrates with and without SAG (temperature at 25 ± 1 ℃)

Table 2. The results of mixed minerals flotation tests (the flotation was continued for a total of 5 min)

| Products | Ratio (W/%) | Gades (%) | | Recoveries (%) | |
|---|---|---|---|---|---|
| | | Cu | MgO | Cu | MgO |
| Cu concentrates | 49.43 | 29.1 | 2.37 | 94.0 | 8.8 |
| Tailings | 50.57 | 1.3 | 26.74 | 6.0 | 91.2 |
| Feed | 100 | 15.2 | 14.7 | 100 | 100 |

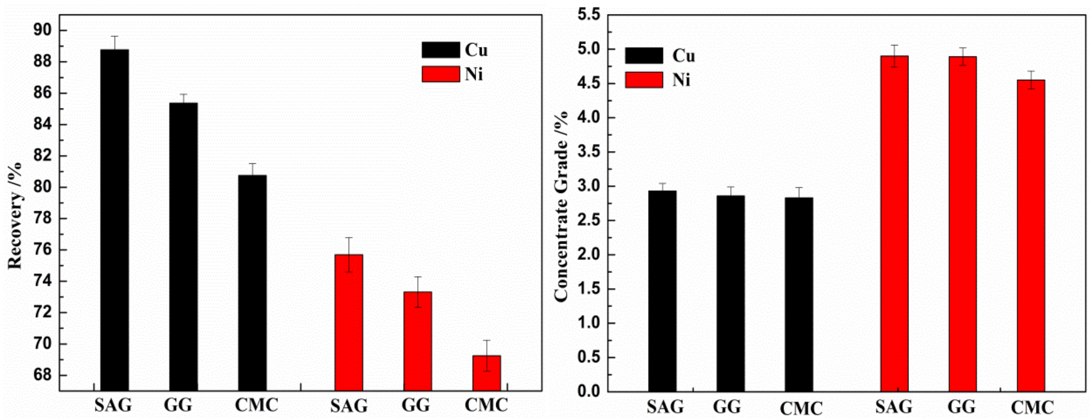


Fig. 7. The effect of different depressants on Ni/Cu grade and recovery in the rougher concentrate (SAG: sodium alginate GG: guar gum CMC: carboxymethyl cellulose.)

### 3.2. Batch flotation tests

The bench-scale locked cycle tests of Cu/Ni bulk flotation were carried out. Under the flotation condition of particle size distribution (90.2% -74 um), oxalic acid (3200 g/Mg, rougher pH 6.0), PAX (200 g/Mg), and MIBC (15 g/Mg), the effects of different depressants on copper/nickel grade and recovery in the rougher concentrate are shown in Fig. 7. The results in Fig. 7 indicated that compared with CMC and guar gum, the SAG decreased the depressant consumption by half at least and increased the recoveries of copper in Cu concentrates by 8.01% and 3.39%, respectively. Besides, the recoveries of nickel in Ni concentrates also augmented by 6.44% and 2.38%, respectively. It is evident from the results in Fig. 7 that the conventional depressants (e.g., CMC and guar gum) not only depressed talc, but also had stronger degrees of depression on copper–nickel minerals. For this low-grade Cu /Ni sulfide ore (Ni/Cu grade of feed is 0.52% and 0.27% respectively), SAG had high depression selectivity for talc and obtained superior Cu and Ni recovery compared to the conventional depressants. The dosage of SAG was confirmed by the subsequent flotation condition tests. As a result, 150 g/Mg SAG were adopted in the rougher operation. It is necessary to note that the room temperature should be kept constant at 25 ± 1 ℃ during the flotation. The SAG may be expressed different suppressed ability and selectivity between talc and sulphide ore since its 'irritability' for temperature. The relevant research will be discussed in the next published outcome.

### 3.3. Adsorption mechanism of SAG on single mineral

In order to investigate the reason for the depressant SAG selectively effect on talc, one needs to evaluate how SAG interacts with the talc and chalcopyrite particles. To ascertain this, the zeta-potential and contact angle as well as the infrared spectrum of mineral particles before and after interacting with SAG were analyzed (Liu et al., 2002).

#### *3.3.1. Zeta-potential measurements*

The zeta-potential of talc untreated and treated with SAG as a function of pH are shown in Fig. 8(a). The results indicated that the iso-electric point (IEP) of talc was at about pH 2.2 (Wang et al., 2005; Zhao et al., 2015), and the surface of talc was negatively charged in the pH range of 2.2–12. After the talc was treated with electronegative SAG, the zeta-potential of talc decreased dramatically, it was likely that the adsorption of SAG on talc surfaces prevented the adsorption of hydroxyl on talc surfaces. Over the pH range of 6–11, the zeta-potential of original talc had a large positive shift, which indicated that SAG could strongly adsorb on talc surfaces at these points.

Fig. 8(b) presents the results of zeta-potential measurements of chalcopyrite before and after interacting with SAG. The results showed that the IEP of chalcopyrite was located at pH 3 , which was basically the same as the IEP of unoxidized chalcopyrite (Feng et al., 2012b; Lin et al., 2017). After interacting with 25 $mg/dm^3$ SAG, the zeta-potential of original chalcopyrite showed no obvious changes at pH 2-6, which indicated that SAG had a negligible effect on the zeta-potential of chalcopyrite at these points, and the adsorption of SAG on chalcopyrite surfaces was weak. However, the zeta-potential of the original chalcopyrite showed obvious changes at pH above 6 after interacting with SAG. It is possibly caused by forming metal hydroxides on chalcopyrite surface especially at pH > 6.5 (Senior et al., 1991).

Fig. 9 indicates that the contact angle of talc remains at 75.14 (Fig. 9A) in the absence of SAG. It is shown that talc has an excellent natural hydrophobicity (Deng et al., 2017). In the SAG system, the contact angles of talc are distinctly reduced (the contact angle of talc decreases to 68.08° at 25 $mg/dm^3$ SAG, as showed in Fig.9(b)) compared with the absence of SAG system throughout pH values. Nevertheless, a slight contact angle difference is observed when SAG and CMC and guar gum are added in the same dosages. The detailed data of contact angle of depressant-reacted chalcopyrite and talc as a function of depressants dosages were shown in Fig. 10. The contact angle measurements are in agreement with the micro-flotation results. It can be inferred from these results that the addition of SAG will sharply reduce the hydrophobicity of talc and will clearly shows less effect on the contact angle of chalcopyrite compared with other depressants like CMC and guar gum. Thus, the wettability difference of chalcopyrite and talc is increased, and the flotation separation of chalcopyrite from talc becomes feasible.

#### *3.3.3 FT-IR spectral analysis*

IR spectrums of SAG and talc conditioned with or without SAG were measured and the results are shown in Figs. 11(a). In the spectrum of SAG, the characteristic sharp band near 3440 $cm^{-1}$ was due to –OH stretching vibration, and the band near 2925$cm^{-1}$ was due to $–CH_2$ stretching vibration. The band near 1649 $cm^{-1}$ corresponded to the stretching vibration of the ring of carbon oxygen six-member ring, and the band near1450 $cm^{-1}$ and 1155 $cm^{-1}$ were due to –COO stretching vibration and C–O stretching vibration in ether, respectively (Chen et al., 2017; Chen et al., 2018). For bare talc, absorption bands at 536 $cm^{-1}$ and 468 $cm^{-1}$ were due to flexural vibrations of Mg-O and Si-O, respectively (Weng et al., 1986; Peng et al., 2017). With SAG treatment, the stretching bands of -OH group appeared at 3411 $cm^{-1}$ and

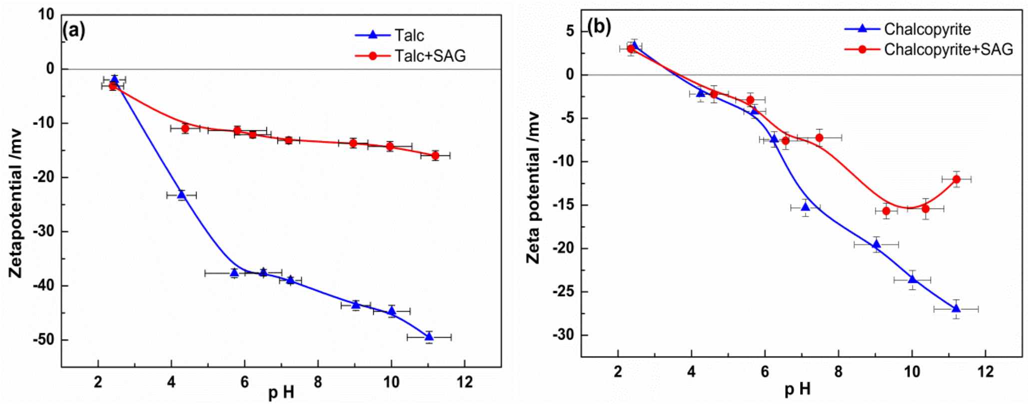


Fig. 8. The zeta potential of (a) talc and (b) chalcopyrite as a function of pH in the presence and absence of SAG with I = $1\times10^{-3}$ M

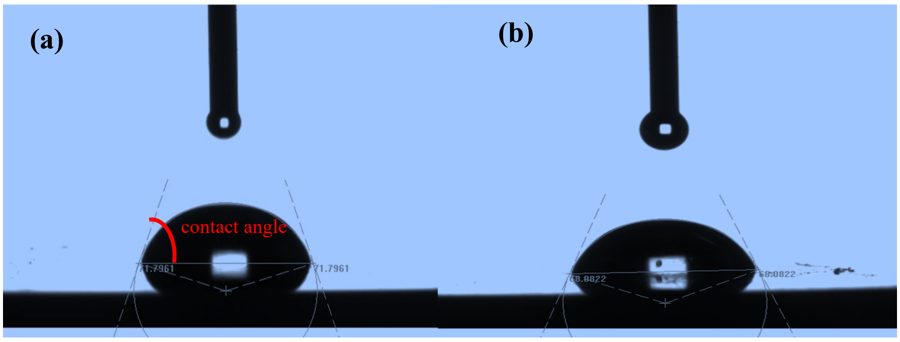


Fig. 9A. Contact angle of chalcopyrite untreated (a) and treated (b) with 25 mg/dm³ SAG at pH 6

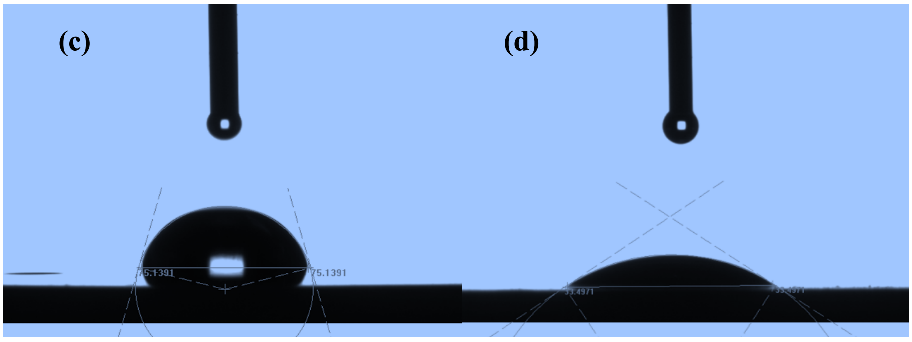


Fig. 9B. Contact angle of talc untreated (c) and treated (d) with 25 mg/dm³ SAG at pH 6

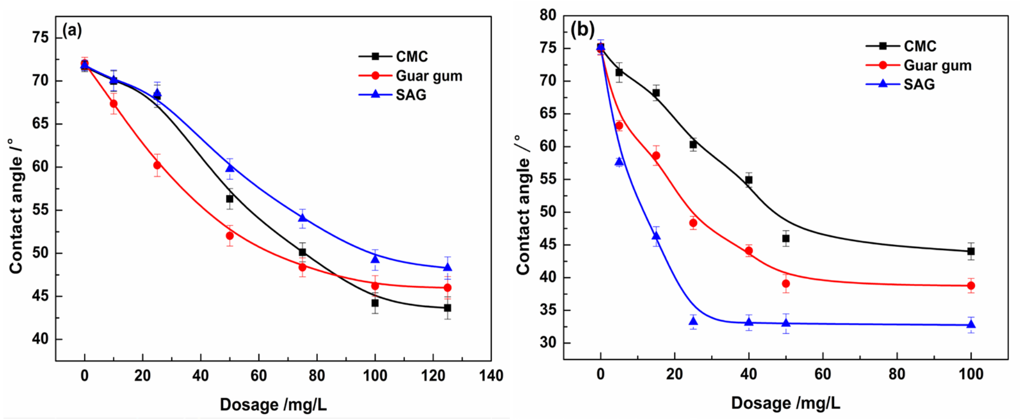


Fig. 10. Contact angle of depressant-reacted (a) chalcopyrite and (b) talc (pH 6) as a function of depressants dosages

new obvious adsorption bands arose near 1459 cm$^{-1}$～1920 cm$^{-1}$, indicating that SAG had adsorbed on the talc surface. Besides, the band of original talc near 536cm$^{-1}$ shifted to 501 cm$^{-1}$. On the whole, these results showing that the adsorption of SAG on talc surface was chemically in essence.

Fig. 11(b) presents the spectra of chalcopyrite untreated and treated with SAG. For bare chalcopyrite, characteristic bands appeared near 1706 cm$^{-1}$, 1515 cm$^{-1}$ and 1029 cm$^{-1}$, respectively. With SAG treatment, the band of original chalcopyrite near 1515 cm$^{-1}$ shifted to 1509 cm$^{-1}$ , other bands shared no obvious changes or no new bands appeared. The results also indicated that SAG had a negligible effect on the FT-IR spectrum of chalcopyrite. Therefore, the adsorption of SAG on chalcopyrite surfaces may have only been weak physical adsorption. Based on the FT-IR spectral analysis, it was concluded that the depressant SAG probably chemical adsorption on talc, but weak physical adsorption on chalcopyrite was, which explained the flotation results.

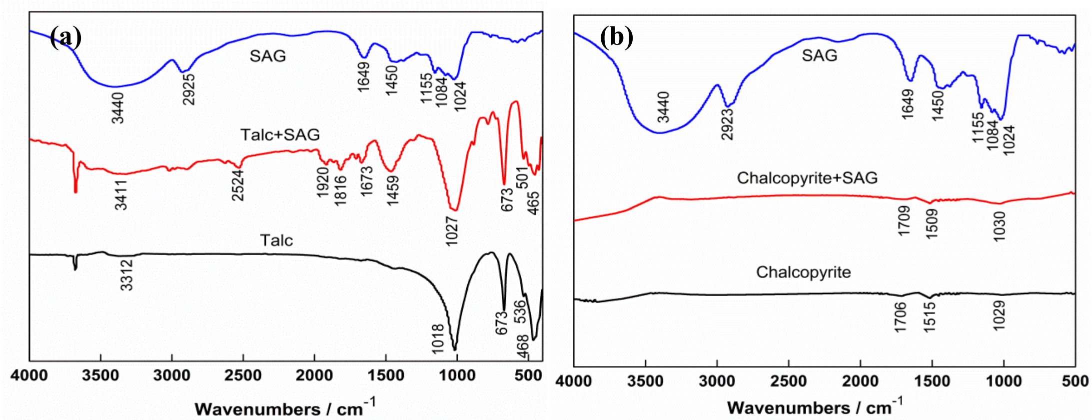


Fig. 11. The FT-IR spectra of (a) talc and (b) chalcopyrite before and after treating with 25 mg/dm3 SAG at pH 6

## 4. Conclusions

Micro flotation tests indicated that the depressant SAG had a weak effect on chalcopyrite flotation, while it could effectively depress the easy-floating talc. The results of closed cycle tests indicated that the effective flotation separation of copper–nickel minerals from the Cu/Ni sulfide ore was realized by using SAG as depressant. Compared with the original plant reagent schedule (using CMC), the SAG decreased depressant consumption by half at least, negating the need for a talc removal process. It not only realized the separation of nickel/copper minerals, but also increased the recovery of copper (8.01%) and nickel (6.44%).

Contact angle results demonstrated that the wettability difference of chalcopyrite and talc is increased, and the flotation separation of chalcopyrite from talc becomes feasible by using SAG as depressant compared with CMC and guar gum. Zeta-potential and infrared spectrum analysis indicated that SAG could be selectively and strongly adsorb on talc surfaces through chemical adsorption while a weak physical adsorption happened between SAG and chalcopyrite. This was the reason why SAG had high depression selectivity for talc and little depression effect on copper–nickel minerals.

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