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Selective depression behavior of guar gum on talc-type scheelite flotation

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Abstract: The depression behavior and mechanism of guar gum on talc-type scheelite flotation were systematically investigated by flotation experiments, adsorption tests, zeta-potential measurements, and infrared spectroscopic analyses. The flotation results for monominerals, mixed minerals, and actual mineral samples indicated that guar gum exhibited much higher selective depression for talc than for scheelite. Bench-scale closed-circuit tests showed that a tungsten concentrate with a WO_3 grade of 51.43% and a WO_3 recovery of 76.18% was obtained. Adsorption tests, zeta-potential measurements, and infrared spectral analyses confirmed that guar gum absorbed more strongly onto the talc surface than onto the scheelite surface because of chemisorption between guar gum and talc. This chemisorption is responsible for the guar gum's highly selective depression for talc and small depression for scheelite. The flotation results provide technical support for talc-type scheelite flotation.

Keywords: scheelite; talc; guar gum; flotation; depression mechanism

1. Introduction

Tungsten deposits, as highly abundant mineral resources in China, can be classified into four categories: quartz-vein type tungsten deposits, quartz-porphyry-disseminated-type tungsten deposits, layer-controlled tungsten deposits, and skarn-type tungsten deposits [1–2]. In this study, talc-type tungsten mineral with special properties was investigated.

Generally, the key problem in scheelite flotation is separation of tungsten from other calcium-containing minerals because these minerals exhibit similar floatability. Scheelite flotation is primarily focused on the depression of calcium-containing minerals [3–5]. In traditional scheelite flotation, apart from sodium silicate and phosphates, organic macromolecules such as carboxymethyl cellulose, lignin, tannin, and dextrin are also used as flotation depressants of calcium-containing minerals, including fluorite and calcite [6–7]. These depressants have large relative molecular mass and contain polar groups (–OH, –COOH, and C=O) in their molecular structures. Guar gum, as a natural polysaccharide, has the advantages of being abundant, nontoxic, and soluble in water. It is therefore commonly used as a depressant of gangue minerals such as quartz and talc. The adsorption of guar gum onto gangue minerals has been studied extensively, which has led to numerous advancements [8–11].

Flotation of the talc-type tungsten mineral has rarely been studied. The sample used in this study is special talc-type tungsten mineral that contains 1.38wt%–1.52wt% WO_3, 0.15wt% S, 1.55wt% P, and 0.026wt% As. The main mineral in the sample is scheelite ($CaWO_4$), and the gangue minerals are talc ($Mg_3[Si_4O_{10}](OH)_2$), chlorite, and calcite. Talc is classified as a hydrous magnesium silicate mineral and exhibits good floatability [12]. Microscopic examination of the sample revealed that the maximum particle size of the scheelite is greater than 1 mm and that the minimum size is 0.001 mm. Additionally, the −0.074-mm fraction accounts for 50wt%–60wt% of the scheelite. The objective of this work was to separate scheelite and talc via flotation.

Preliminary experiments demonstrated that the minerals were very difficult to separate using flotation. When a fatty acid collector was used for scheelite flotation, a large amount of sodium silicate could not depress the talc. When

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carboxymethyl cellulose, lignin, and tannin were used as depressants, both scheelite and talc were depressed, indicating that effective separation of scheelite and talc could not be achieved using conventional depressants.

On the basis of a large number of tests on depressants, we selected guar gum as the depressant of the talc-type tungsten minerals. Guar gum selectively depressed gangue minerals, including talc, thereby improving the flotation separation of scheelite and talc. In this work, the experimental part included flotation experiments on single and mixed binary minerals as well as a real ore sample. The adsorption mechanism was investigated through adsorption, zeta-potential, and Fourier transform infrared spectroscopy (FTIR) measurements.

2. Experimental

2.1. Materials

The sample of scheelite was obtained from Xianghualing Tin Co. Ltd., China, and talc was obtained from Changsha Ore Powder Factory, China. The samples were crushed, hand-picked, ground in a porcelain ball mill, and then dry-sieved. The fraction of +37 to −74 μm was used for microflotation tests. The purities of scheelite and talc were 92.53% and 95.56%, respectively. Samples further ground to −5 μm in an agate mortar were used for zeta-potential measurements and infrared spectroscopic analysis.

The sample of actual talc-type tungsten mineral for batch flotation was obtained from a deposit in Hunan Province, China. The sample was crushed, ground, and screened to −3 mm. The chemical composition of the sample is shown in Table 1.

The hydrochloric acid, sodium hydroxide, sodium carbonate, guar gum, and sodium oleate used in the study were of analytical grade. The relative molecular mass of guar gum was approximately 2×10^6. Deionized water was used for microflotation tests, zeta-potential measurements, and infrared spectroscopy; its resistivity was greater than 18 MΩ·cm. Tap water was used for batch flotation tests. All experiments were conducted at room temperature.

Table 1. Chemical analysis results for the talc-type tungsten sample wt%

WO_3	SiO_2	Al_2O_3	CaO	CaF_2	MgO	S	P	As
1.45	46.01	10.45	17.38	1.56	24.38	0.15	1.55	0.026

2.2. Experimental methods

Microflotation tests were conducted in an XFG flotation machine with a volume of 40 mL. The sample (2.0 g) and the solution with reagents were added to the flotation cell and agitated for 5 min; the flotation test was then carried out for 4 min after the pulp pH had been adjusted to the desired operating value. Batch flotation tests were conducted using 1.5-L, 1-L, and 0.5-L XFG flotation machines. The obtained products were dried and weighed, and the yield was calculated on the basis of the mass balance. In the case of monominerals, the yield was equal to the flotation recovery. For mixed and actual minerals, flotation recovery was calculated on the basis of the chemical analysis results for the products.

Adsorption capacity was determined using a TU-1810 UV–Vis spectrophotometer. A guar gum solution was treated with phenol sulfuric acid for visualization; the wavelength corresponding to the characteristic absorption peak of the treated guar gum was 487.5 nm [13]. On the basis of the absorbance of guar gum solutions with various guar gum concentrations, a calibration curve was constructed to determine the relationship between guar gum concentration and absorbance. The guar gum concentration after absorption was determined using the calibration curve. The adsorption capacity was calculated on the basis of the change in guar gum concentration.

Zeta potentials were measured using a DELSA-440SX zeta-potential analyzer. The sample for analysis (30 mg) was mixed with 50 mL of deionized water containing corresponding reagents; the resulting suspension was stirred for 5 min and then allowed to settle for another 10 min. The pH level of the solution was adjusted with diluted HCl or NaOH solutions. All measurements were performed as a function of the pH level. The results presented are the average of three independent measurements, with a typical variation of ±5 mV.

The FTIR analysis was carried out using a Nicolet FTIR-740 Fourier transform infrared spectrometer. The sample (2.0 g) was mixed with guar gum solution and stirred sufficiently. After filtration, a vacuum-drying method was used to obtain the solid for subsequent infrared spectrum measurements.

3. Results and discussion

3.1. Flotation experiments

The effect of pH level on the flotation recovery of monominerals is shown in Fig. 1. Talc showed good flotability in the absence of guar gum, and the flotation recovery was greater than 97%. The flotation recovery of scheelite increased with increasing pH level and reached 80% at pH levels greater than 8. After guar gum was added, the flotation recovery of talc was reduced by 80%, whereas that of scheelite decreased slightly. At pH levels between 8 and 9.5, the flotation recoveries of scheelite and talc were approximately 75% and 16.5%, respectively. Obviously, guar gum depressed talc more strongly than scheelite. The proper pH level was selected as 8.5.

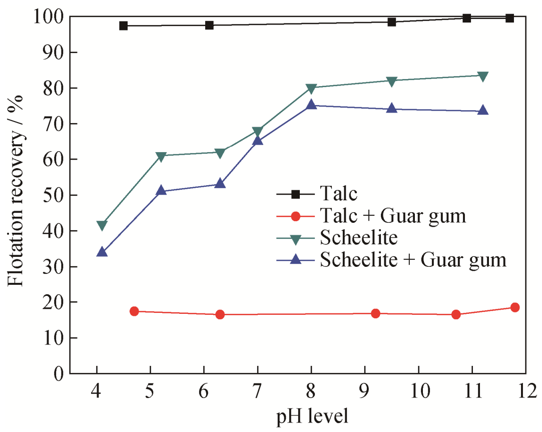

Fig. 1. Effect of pH level on the flotation recovery of monominerals (guar gum concentration: 20 mg/L; sodium oleate concentration: 50 mg/L).

The effect of guar gum concentration on the flotation recovery of monominerals is shown in Fig. 2. With increasing guar gum concentration, the recovery of talc decreased sharply; it was less than 17% when the guar gum concentration was greater than 20 mg/L. In the case of scheelite, the recovery decreased from 80.2% to 70.6% as the concentration of guar gum was increased from 0 to 60 mg/L. These results indicate that guar gum exhibited high selectivity for depressing talc. A guar gum concentration of 20 mg/L was chosen as the optimum condition.

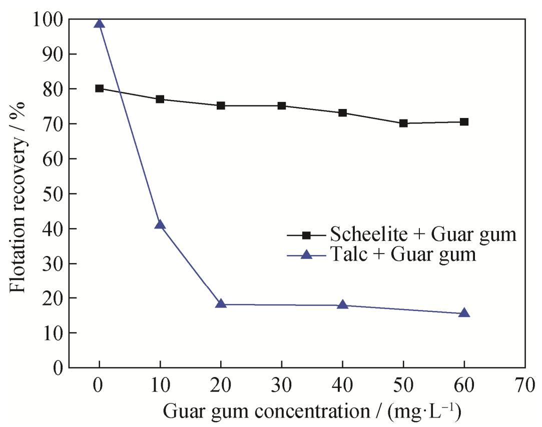

Fig. 2. Effect of guar gum concentration on the flotation recovery of monominerals (pH 8.5).

To further confirm the selective depression of guar gum, flotation separation of the mixture of scheelite and talc (with a mass ratio of 1:1) was conducted under the conditions of a guar gum concentration of 20 mg/L, a sodium oleate concentration of 50 mg/L, and pH 8.5. As displayed in Table 2, effective separation of scheelite and talc was achieved. The grade and recovery of WO_3 in the concentrate were 69.55% and 94.21%, respectively, whereas the grade of MgO was reduced to 2.56%. These results demonstrate that the guar gum separated scheelite from talc effectively. Therefore, guar gum can be considered as a good depressant for the flotation separation of scheelite and talc.

Table 2. Flotation separation results of mixed scheelite and talc

Products	Yield / %	Grade / %		Recovery / %	
		WO_3	MgO	WO_3	MgO
Concentrate	49.28	69.55	2.56	94.21	8.08
Tailing	50.72	4.15	28.29	5.79	91.92
Raw	100.00	36.38	15.61	100.00	100.00

Batch flotation tests were carried out using sodium carbonate as a pH regulator, guar gum as a depressant, and sodium oleate as a collector. The closed flotation circuit is shown in Fig. 3; it includes one roughing, three scavenging, and five cleaning steps. The results are displayed in Table 3. The grade and recovery of WO_3 in the tungsten concentrate were 51.43% and 76.18%, respectively, implying that guar gum was a powerful depressant and had excellent selectivity depression for talc-type tungsten minerals. This study solved the problem of flotation separation of scheelite and talc, which could provide technical support for the flotation recovery of talc-type scheelite.

3.2. Adsorption tests

The selective depression behavior of guar gum is attributed to its adsorption onto the mineral surface. The adsorption behavior of guar gum on monominerals is shown in Fig. 4. The adsorption capacity of scheelite and talc increased with increasing concentration of guar gum, and the adsorption capacity of talc was greater than that of scheelite. Thus, guar gum could absorb selectively onto the talc surface, increasing the difference in floatability between scheelite and talc. Additionally, the results of adsorption tests are consistent with flotation results shown in Fig. 2.

3.3. Zeta-potential measurements

The zeta potentials of scheelite and talc in the absence and presence of guar gum are shown in Fig. 5. The zeta-potential of talc at different pH levels was negative and became increasingly negative with increasing pH level. The zeta-potential of scheelite decreased with increasing pH level and became negative. The points of zero charge of talc and scheelite were pH 2.2 and 4.3, respectively, consistent with previously reported values [14–15]. The adsorption of guar gum remarkably increased the surface potential of talc at pH levels above 6.4. Guar gum, as a nonionic depressant, can absorb onto the talc surface through electrostatic interaction, which may lead to strong chemical interaction between talc and guar gum. The guar gum had little effect on the surface potential of scheelite, indicating that little guar gum absorbed onto the scheelite surface. This interpretation is consistent with the results of the adsorption experiments. Fig. 6 presents the model of guar gum adsorption onto the surfaces of talc and scheelite.

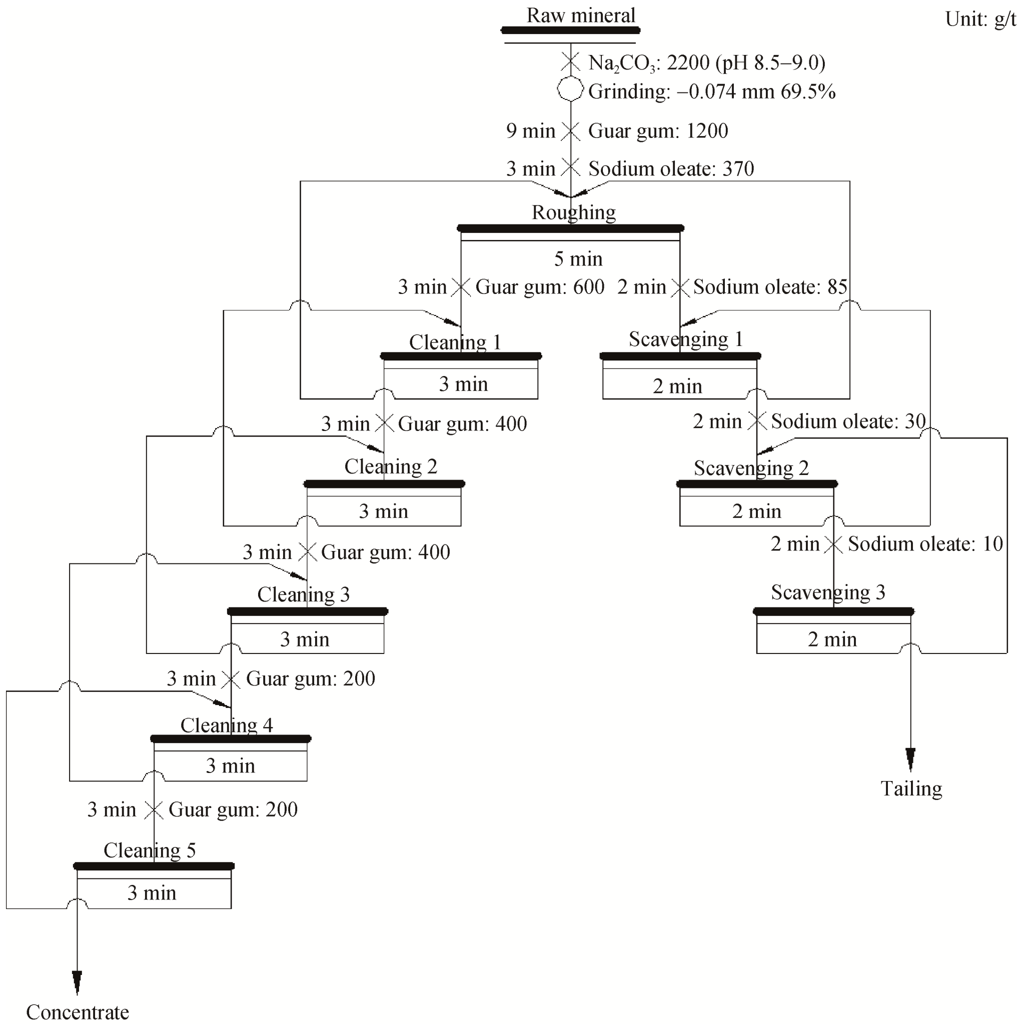

Fig. 3. Closed flotation circuit for talc-type scheelite flotation.

Table 3. Results of closed flotation circuit of talc-type scheelite

Products	Yield / %	WO_3 grade / %	WO_3 recovery / %
Concentrate	2.13	51.43	76.18
Tailing	97.87	0.35	23.82
Raw	100.00	1.44	100.00

3.4. FTIR analysis

The selective depression mechanism was further investigated by FTIR analysis. As shown in Fig. 7, in the spectrum of guar gum, the band at 3448.9 cm^{-1} was attributed to the vibration of –OH groups on the molecular chains of guar gum, and the band at 1647.9 cm^{-1} was attributed to a $–CH_2$ stretching vibration. The bands at 1010.8 and 449.5 cm^{-1} were attributed to a C–O stretching vibration [16–17]. The spectrum of talc showed bands at 2514.6, 1795.3, 1463.6, and 877.8 cm^{-1}, which were assigned to –OH vibration, Si–O stretching vibration, Mg–O bending, and Si–O bending, respectively [12]. After the talc interacted with guar gum, its spectrum showed new bands at 3415.9, 1646.8, 1074.3, and 453.5 cm^{-1}. In addition, the Mg–O bending band shifted from 1463.6 to 1460.3 cm^{-1}. These results imply that chemisorption occurred between talc and guar gum.

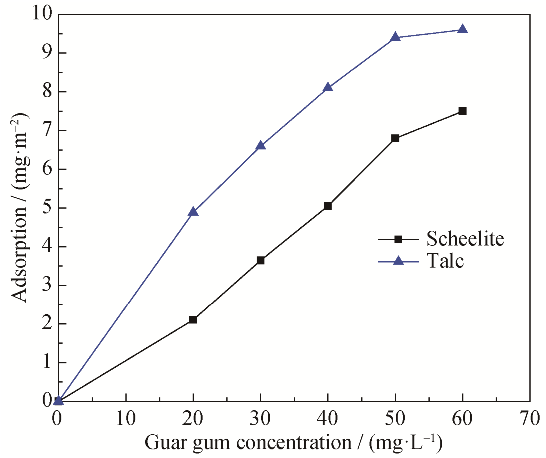

Fig. 4. Effect of guar gum concentration on the adsorption capacity of monominerals (pH 8.5).

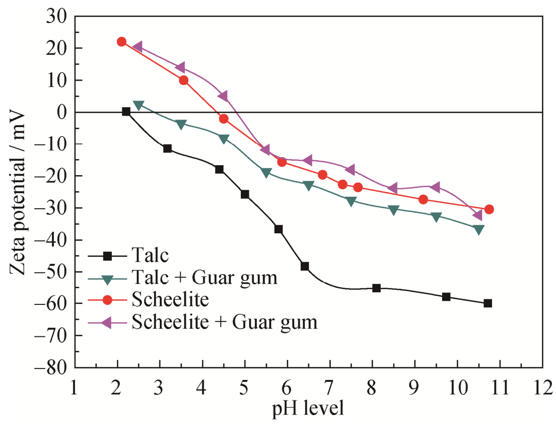

Fig. 5. Zeta-potential of scheelite and talc at different pH levels (guar gum concentration: 20 mg/L).

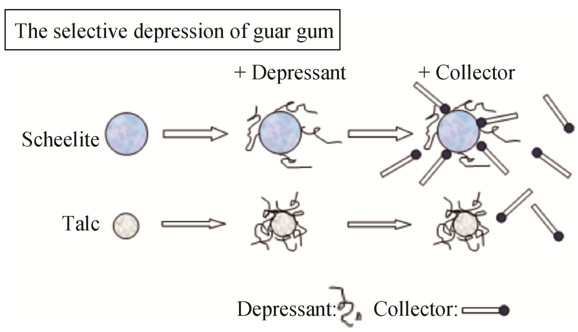

Fig. 6. Model of guar gum adsorption onto the surfaces of talc and scheelite.

Fig. 8 shows the FTIR spectra of guar gum and scheelite. The spectrum of scheelite presented bands at 1106.3 and 799.9 cm^{-1} assigned to an asymmetric stretching vibration and bending vibration of W–O bonds [18–19]. After scheelite interacted with guar gum, the spectrum showed no obvious change, indicating that no obvious interaction occurred between guar gum and scheelite. These results are consistent with the zeta-potential results.

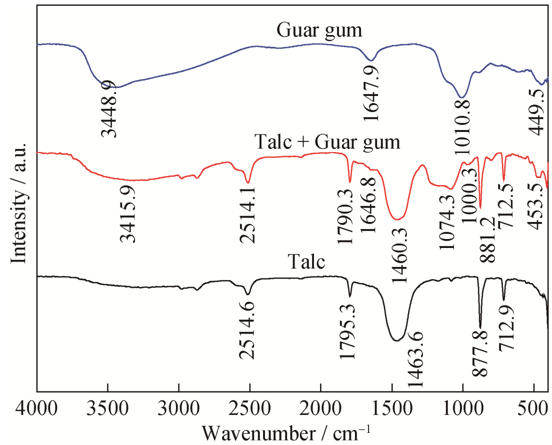

Fig. 7. FTIR spectra of guar gum and talc (pH 8.5; guar gum concentration: 20 mg/L).

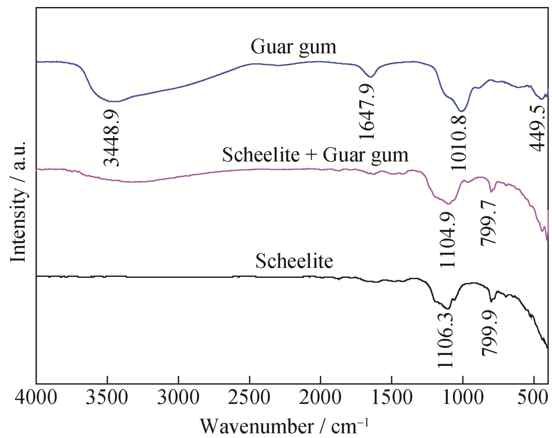

Fig. 8. FTIR spectra of guar gum and scheelite (pH 8.5; guar gum concentration: 20 mg/L).

4. Conclusions

(1) Guar gum has high selectivity for depressing talc. When guar gum was used as the depressant for the flotation of mixed talc and scheelite, the grade and recovery of WO_3 in the concentrate were 69.55% and 94.21%, respectively, and the MgO content was reduced to 2.56%. When guar gum was used for the flotation of an actual mineral sample, the grade and recovery of WO_3 in the resulting tungsten concentrate were 51.43% and 76.18%, respectively. This study solves the problem of flotation separation of scheelite and talc, providing technical support for the flotation recov-

ery of talc-type scheelite.

(2) Selective adsorption of guar gum onto the talc surface strongly influenced the surface potential of talc; this strong effect was attributed to strong chemisorption. Guar gum weakly absorbed onto the surface of scheelite and had little effect on its surface potential. A mechanism consistent with the flotation results was proposed.

Acknowledgements

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