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The effect of polyether on the separation of pentlandite and serpentine

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ABSTRACT

The effect of polyether on the separation of pentlandite from serpentine has been studied. In addition to flotation and sedimentation tests, electrophoresis and adsorption tests have been conducted. The flotation and sedimentation results show that serpentine impairs flotation performance of pentlandite, by adhering to the pentlandite particles. Addition of the polyether could promote the dispersion of the mixed sample of pentlandite and serpentine in alkaline conditions and significantly reduce adverse effects of serpentine on the pentlandite flotation. The electrophoresis and adsorption tests show that polyether can selectively adsorb onto pentlandite surface through hydrophobic reaction and remove serpentine slime particles from pentlandite surfaces by steric hindrance effect.

1. Introduction

Serpentine is a magnesium-rich phyllosilicate mineral occurring in complex sulphide ores [1,2]. In nickel sulfide ore processing, serpentine may report to flotation concentrate through attachment to the valuable minerals as "slime coatings" [3–5]. As a kind of magnesium silicate gangue mineral, large quantities of serpentine in flotation concentrates can cause problems during smelting, often resulting in the imposition of smelter penalties for mineral processing companies [6]. In addition, these hydrophilic serpentine minerals may interfere with the flotation of valuable sulfide minerals, such as pentlandite [3,7]. A coating of hydrophilic slime particles will decrease the hydrophobicity of the sulfide particle and may also reduce collector adsorption [8]. Either of these situations will reduce the floatability of sulfide particles. For example, a hydrophobic sulfide particle coated with hydrophilic slime particles may become increasingly hydrophilic. Consequently, hydrophobic particles may take longer time to attach to a rising bubble or may even not float at all [9]. In order to improve the flotation of the nickel sulfide ore, sodium hexametaphosphate, carboxymethyl cellulose (CMC) and other agents are used to disperse slime particles from sulfide surfaces [10,11]. Adsorption of these reagents on serpentine reverses its positive surface charge. Therefore, attraction forces between pentlandite and serpentine particles are eliminated [12,13]. However, high reagent dosages are needed in dispersing serpentine slime.

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In this investigation, the effect of polyether on the separation of pentlandite from serpentine has been studied. The aim of this study is to find a new reagent that can disperse serpentine slime from sulfide surface by react with pentlandite.

2. Experimental

2.1. Samples and reagents

The serpentine used for all experiments was obtained from Donghai, Jiangsu Province, China. The mineral composition of the serpentine selected for experiments as determined by XRD was as follows: serpentine 98%, chlorite 2%. The sample was dry ground and screened. The particle size distribution determined using a Malvern Instruments Master sizer was 100% – 10 μm, with a D50 of 3.94 μm, a D90 of 9.62 μm and an average diameter of 6.17 μm. The BET surface area of the sample was $39\,m^2\,g^{-1}$.

The pentlandite sample was prepared using "pentlandite rocks" from Jinchuan, Gansu Province, China. This sample was passed through a magnetic separator three times to remove the magnetic pyrrhotite fraction. The non-magnetic fraction containing the pentlandite was dry ground and screened. The −150 + 75 μm fraction was used for the flotation tests. The BET surface area of the −150 + 75 μm pentlandite was $1.27\,m^2\,g^{-1}$.

The polyether was purchased from BASF Company. The molecular formula of the polyether is $HO\cdot(C_2H_4O)_m\cdot(C_3H_6O)_n\cdot H$. PAX (potassium amyl xanthate) and MIBC (methyl isobutyl carbinol) were used as collector and frother, respectively. Potassium nitrate was used to maintain ionic strength and HCl (hydrochloric acid) and KOH (potassium hydroxide) were used as pH regulators. All the reagents used in this study were of analytical grade. Distilled water was used for all tests.

2.2. Experiments

2.2.1. Flotation tests

Single mineral flotation tests were carried out in a mechanical agitation flotation machine. The impeller speed was fixed at 1800 rpm. The mineral suspension was prepared by adding 2.0 g of pentlandite to 40 mL of distilled water. Serpentine was added at the beginning of the conditioning period. The pH of the mineral suspension was adjusted to the desired operating value by adding KOH or HCl stock solutions. Collector and frother were added sequentially with 3 min of conditioning for each stage. Flotation concentrates were then collected for a total of 4 min. The flotation concentrates and tailings were collected, filtered and dried. The flotation recovery was calculated based on solid weight distributions between the two products.

2.2.2. Sedimentation tests

Coagulation and dispersion between serpentine and pentlandite were studied using the sedimentation tests. For the sedimentation tests, 0.1 g of sample powder was taken and made up to 100 mL after addition desired amounts of 0.001 M KNO_3. The suspensions were then agitated for half an hour using a magnetic stirrer at 25 °C and transferred to 100 mL graduated flasks. The solution was then settled at a fixed time (3 min), and the supernatant liquor of fixed height (25 mL) was pipetted out and measured by scattering turbidimeter. The dispersion of the supernatant liquor was characterized by its turbidity. The higher the turbidity value is, the better dispersed the sample is.

2.2.3. Zeta potential measurements

Zeta potential measurements on pentlandite and serpentine were carried out using a zeta potential meter. Potassium nitrate was used to maintain the ionic strength at 10^{-3} mol/l. Small amounts of sample were added to desired amounts of solution and ultrasonicated for 3 min, magnetically stirred for 10 min, and the pH was adjusted using HCl or KOH. Pulp pH was recorded using a pH meter (LeiCi PHS-3). The zeta potential of samples was then measured using a zeta potential meter.

2.2.4. Adsorption tests

For the adsorption tests, 1 g of mineral powder was taken and made up to 100 mL after addition of desired concentration of polyether solution in 250 mL Erlenmeyer flasks. The suspensions were mixed and placed on a rotator for 1 h (which should occur within 5 min but longer times were used as a precaution), ensuring that the adsorption process had reached equilibrium. Each sample was then centrifuged and the concentration of polyether left in solution was analyzed. The concentration of polyether solution cannot be directly detectable by UV–vis spectroscopy. However, when tannic acid is mixed with the polyether solution, they will react and form a complex, which by increasing the turbidity of the solution, is detectable by UV–vis spectroscopy [14]. The turbidity is a function of the polyether concentration. It was assumed that the amount of polyether depleted from solution had adsorbed onto the mineral phase.

3. Results and discussion

Fig. 1 shows the effect of serpentine concentration on the flotation recovery of pentlandite at pH 9. The recovery of pentlandite decreased with increasing serpentine concentration. When the ratio of serpentine to pentlandite is over 1:10, there was almost total depression.

In Fig. 2, the flotation recovery of pentlandite can be observed as a function of pH in the absence and presence of serpentine. The flotation recovery of pentlandite in the absence of serpentine is very high (>85%) under acidic and neutral conditions. With increases in pH, pentlandite recovery decreased due to formation of hydrophilic iron oxy-hydroxy species on the surface [12]. When serpentine particles were added prior to collector addition, the recovery of pentlandite decreased with increasing pH from a maximum recovery of 90% to 2%.

The effect of polyether concentration on the flotation performance of pentlandite that has been depressed by serpentine is shown in Fig. 3. The result shows that the addition of polyether could significantly weaken the depression effect of serpentine on the flotation performance of pentlandite. A maximum increase in pentlandite recovery was obtained

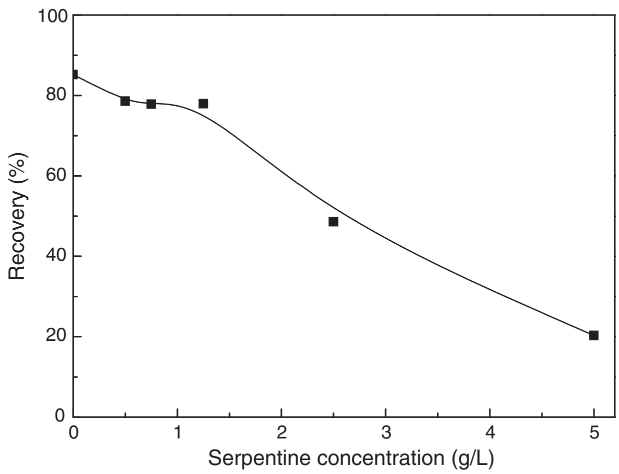

Fig. 1 – Effect of serpentine concentration on the flotation of pentlandite (PAX = 1 × 10^{-4} M; MIBC = 1 × 10^{-4} M; pH 9; [pentlandite] = 50 g/L).

with 100 mg/L polyether, while higher polyether concentrations produce little gain in recovery.

The effect of pH on the floatability of pentlandite in the absence and presence of polyether is shown in Fig. 4. Apparently, when fine serpentine particles were added prior to collector addition, the flotation recovery of pentlandite is steadily decreased with the increases of pH from 2 to about 11 in the absence of polyether. In the pH range of 3–11, the use of polyether could eliminate the depression effect of serpentine and restore the pentlandite floatability.

The attachment of serpentine slimes to the valuable minerals as "slime coatings" is the main reason that serpentine slimes interfere with pentlandite flotation. The effect of polyether on the aggregation and dispersion behavior of pentlandite and serpentine is studied by sedimentation tests. Turbidity technique has been widely used for studies of colloidal suspensions due to its non-invasive and non-contact properties. The turbidity value of suspensions reflects the

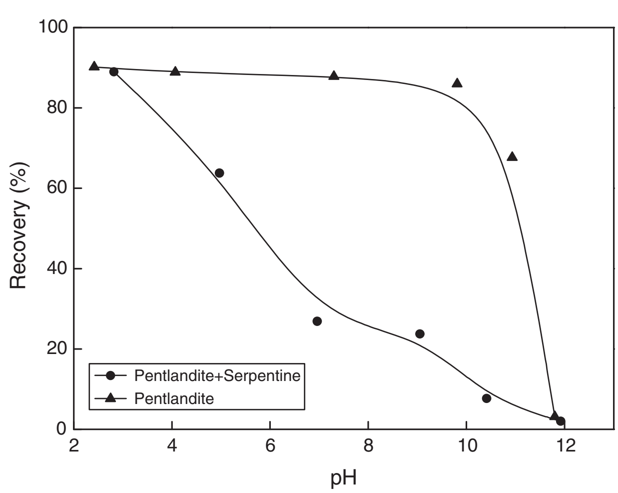

Fig. 2 – Recovery of pentlandite as a function of pH in the absence and presence of serpentine (PAX = 1 × 10^{-4} M; MIBC = 1 × 10^{-4} M; [pentlandite] = 50 g/L; [serpentine] = 5 g/L).

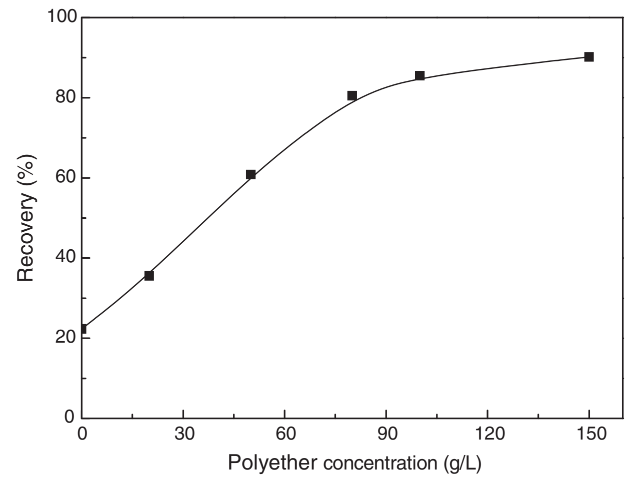

Fig. 3 – Recovery of pentlandite as a function of polyether concentration (PAX = 1 × 10^{-4} M; MIBC = 1 × 10^{-4} M, pH 9).

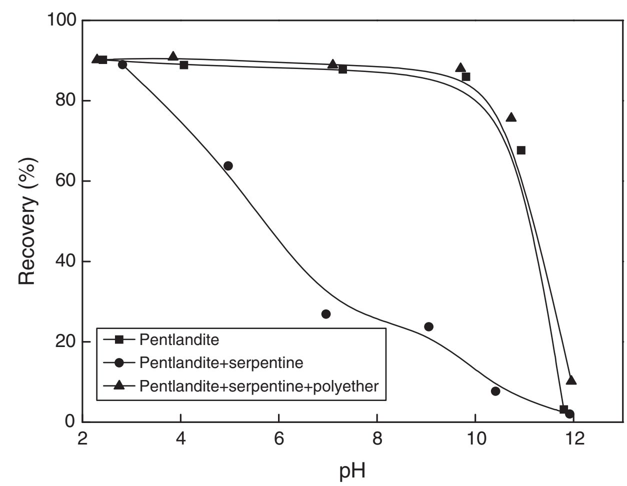

Fig. 4 – Recovery of pentlandite as a function of pH (polyether = 1 × 10^{-4} M; PAX = 1 × 10^{-4} M; MIBC = 1 × 10^{-4} M).

particle numbers of colloidal suspensions. A decrease of turbidity value indicates a decrease in particle number, resulting from particle aggregation.

The turbidity of mixed ores as a function of pH in the absence and presence of polyether is shown in Fig. 5. It can be seen from Fig. 5 that the polyether could effectively disperse mixed ores in the pH range of 4–12. In the presence of polyether, the turbidity of mixed ores is higher than the value obtained in the absence of polyether.

The adsorption of polyether on mineral surfaces was studied and the result is shown in Fig. 6. The result shows that the adsorption of polyether on pentlandite is significantly higher than on serpentine surface. According to the literature, the adsorption of polyether on to mineral surfaces is the result of hydrophobic interaction [15]. Therefore, polyether is selectively adsorbed on hydrophobic pentlandite instead of hydrophilic serpentine.

The adsorption of polyether on serpentine surface may change the surface characteristic of serpentine. As a direct surface chemistry investigation of the different minerals,

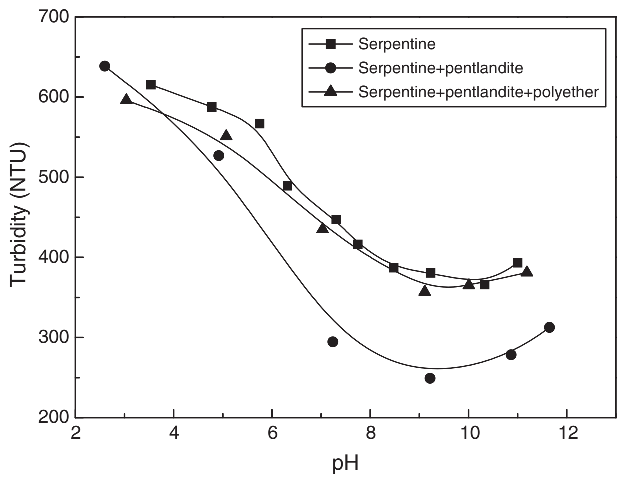

Fig. 5 – Turbidity of serpentine and pentlandite as a function of pH in the presence of polyether.

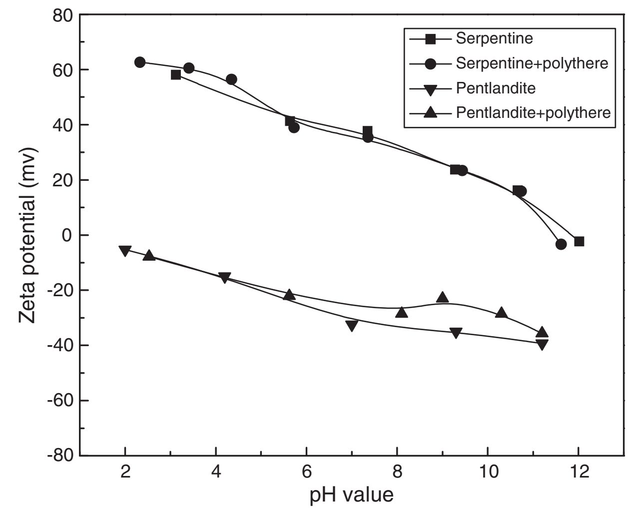

Fig. 7 – Zeta potential of serpentine and pentlandite particles as a function of pH.

individual electro-kinetic studies were conducted for pentlandite and serpentine particles as a function of pH in 0.001 M KNO_3. It can be seen from Fig. 7 that serpentine has an IEP of around pH 11.8. The zeta potential of serpentine is positive in the pH value range of 2–11.8. The surface of pentlandite is negatively charged in the pH value range of 2–12. At pH value 9, where flotation of nickel sulfide ores is usually performed, surface potential of serpentine and pentlandite are opposite, the positively charged fine serpentine particles will attach to the negatively charged pentlandite particle surface through electrostatic attraction. The addition of polyether does not have effect on the zeta potential of serpentine and pentlandite.

Thus, the dispersion effect of polyether is different from the other reagents, which disperse serpentine slime particles from sulfide surfaces through reacting with serpentine. The hydrophobic component of polyether will approach the hydrophobic sites on pentlandite surface and push the slimes particles away from the surfaces due to steric hindrance.

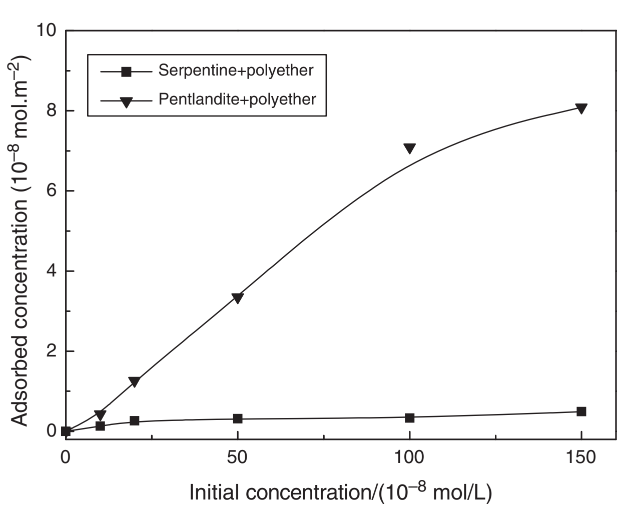

Fig. 6 – Adsorption of polyether on serpentine and pentlandite.

4. Conclusions

From the results of this investigation, the following conclusions can be drawn:

(1) Polyether can effectively disperse the serpentine and pentlandite, reducing the coverage of serpentine on pentlandite and improving the flotation performance of the pentlandite.
(2) The adsorption density of polyether on pentlandite particle surfaces is about 10–20 times greater than that on serpentine particle surfaces. Hydrophobic bonding is the dominant interaction for polyether adsorption on to pentlandite surfaces.
(3) Polyether may adsorb onto pentlandite surface sites, significantly increase the adsorption layer thickness between the slime particles and the pentlandite surface, and consequently reduce the attractive force between the slime particles and pentlandite surface by steric hindrance.

Conflict of interest

The authors declare no conflict of interest.

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