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DEPRESSION EFFECT OF CORN STARCH ON MUSCOVITE MICA AT DIFFERENT pH VALUES

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Abstract: The depression effect of corn starch on the surface of muscovite mica powder at different pulp pH value was investigated. The experiments were performed on single mineral, and its flotation performance was studied by flotation tests, adsorption quantity measurement, zeta-potential technique and Fourier transform infrared (FT-IR). The results indicated that the depression effect was varied with the pulp pH value when dodecylamine chloride (DDA) was used as collector, the strongest inhibitory effect appeared at pH 2 and the zeta-potential of muscovite mica increased overall after conditioned with corn starch solution. It was confirmed by the FT-IR spectra that the corn starch indeed adsorbed on the surface of muscovite mica powder and physical adsorption was occurred between muscovite mica and corn starch. This study leads to a better understanding of the depression effect of corn starch on the surface of muscovite mica powder.

Keywords: *muscovite mica, corn starch, pulp pH, depression effect*

Introduction

Muscovite mica is a layer structure silicate minerals, which is composed of two silica tetrahedral sheets with a central aluminum octahedral sheet (Nosrati et al., 2009; 2011). It is widely used in electronics, electricity, telecommunications, aviation, transportation, instrumentation, metallurgy, building materials, light industry etc., as well as the defense and sophisticated industrial insulation materials, due to its high electrical and heat resistance, high electric insulating, corona resistance, and good mechanical properties and chemical stability, small shrinkage rate at the same time, not burning and hygroscopic etc. (Yu et al., 2011).

Starch is one of the most important polysaccharides that have been applied in mineral processing, especially in froth flotation due to its adsorption onto the surfaces of minerals (Weissemborn et al., 1995). Corn starch is extensively utilized in the mineral processing industry as depressant in froth flotation (Pavlovic et al., 2003). The

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depressant action of corn starch is due to the coating of a natural low energy hydrophobic surface with a hydrophilic film to prevent the attachment of air bubbles (Turrer et al., 2010).

Over the past several decades, a great deal of effort has been committed to the study of the collectors for the flotation of muscovite mica (Xu et al., 2013; Wang et al., 2014). The research of corn starch as depressant is mainly concentrated on the flotation of iron ore (Pavlovic et al., 2003; Lima et al., 2013). Great existed studies mainly focused on the flotation technique, process and collectors of muscovite mica ores, while little efforts have been devoted to the depression effect of corn starch on the surface of muscovite mica powder (Xu et al., 2013; Wang et al., 2014). The depression effect of corn starch on the surface of muscovite mica powder is still unsolved.

The objective of this study was to improve the understanding of the depression effect of corn starch on the surface of muscovite mica powder at different pulp pH, to contribute to explaining the depression mechanism on muscovite mica flotation with dodecylamine chloride as collector.

Experimental

Materials

Muscovite mica, taken from Lingshou of Hebei Province (China), was crushed by a hammer and ground in a porcelain ball mill. The size ranges from 74 µm to 45µm was used in the experiments, which was repeatedly cleaned with deionized water first. X-ray diffraction (XRD) was used to study the mineral composition of the muscovite mica (Fig. 1.). The purity of muscovite mica was approximate 94 wt.%.

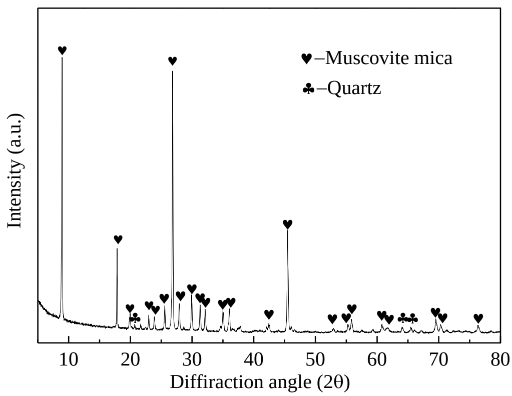

Fig. 1. X-ray diffraction pattern of muscovite mica

Dodecylamine chloride (DDA) (analytical reagent) from the Foshan Nanhai Jiang Shun chemical products factory, was used as collector and frother. Sulfuric acid of analytical purity was from Henan Billions Chemicals Co., LTD and used to adjust the pH of the system. Corn starch was bought in the market, used as inhibitor. Corn starch was added into a certain amount of deionized water first, and then heated the system to boiling state, kept stirring when heating, until the solution turned into bear yellow.

Flotation tests

A series of flotation tests were performed in a 30 cm^3 XFG hitch groove type flotation machine with the stirring rate of 1960 rpm. For each test, 2 g sample was added into the flotation cell, and then filled with the solution which pH had been adjusted by sulfuric acid. After stirring 3 min, a certain amount of corn starch solution was added into as the inhibitor of muscovite mica, and then some dodecylamine chloride solution was added into 3 min later. Flotation was conducted for 3 min after agitation for 3 min. The froth products and tails were weighed respectively after filtration and drying, and the recovery was calculated based on the weight of the products.

Corn starch adsorption quantity measurement

The quantity of corn starch absorbed on the surface of muscovite mica powder at different pulp pH was measured according to the residual concentration method (Wang et al., 2014). First, a series of different concentration corn starch solution were prepared, and the same volume of 0.2 wt.% iodine solution was added as indicator respectively, the absorbance of the different concentration solution was measured by V-1100D spectrophotometer (Mapada, China). The increment of color was proportional to the concentration of corn starch, so ultraviolet spectrophotometer can be used to measure the residual corn starch concentration in slurry (Pavlovic et al., 2003). The absorbance was exactly linear dependency on the corn starch concentration and the slopes of the straight line were obtained by linear least square regression. The residual concentration of corn starch was calculated from the slope by using the Beer-Lambert law (Li et al., 2005).

The adsorption experiments included the transfer of 2 g muscovite mica to the flotation cell. The sample was suspended in deionized water at different pH with further additions of a certain quantity of the corn starch solution. The final quantity of the total suspension was adjusted to 30 cm^3, and the cell was stirred at room temperature for 10 min. The mineral suspension was centrifuged at 4000 rpm for 20 min, and the absorbance of supernatant was measured. The residual concentration of corn starch was traced through the fitted line, the adsorption of corn starch on the surface of muscovite mica could be calculated by Eq. 1 (Hu et al., 1991):

$$\tau = \frac{V(C_0 - C)}{1000m} \tag{1}$$

where: τ is the adsorption amount, C_0 initial concentration of corn starch, g/dm^3 and C residual concentration of corn starch, mg/dm^3, V volume of corn starch solution, cm^3, and m mass of muscovite mica, g.

Zeta-potential measurement

A suspension solution containing 0.1 wt.% muscovite mica particles which had ground to -1.0 μm in a three head agate grinding machine were prepared in $1\cdot10^{-3}$ mol/dm^3 NaCl solution, and dispersed by magnetic stirring for 5 min. A certain amount of the suspension solution was then taken for zeta potential measurement. The zeta-potentials were measured using a Malvern Zetasizer Nano ZS90 (UK) equipped with a rectangular electrophoresis cell. The conductivity and pH value of the suspension solution were monitored continuously during the measurement and the environmental temperature was maintained at 25 °C.

FT-IR measurement

Fourier transform infrared (FT-IR) spectra were carried out on a Bruker Vector-22 (Germany), for which samples were prepared in potassium bromide pellets and the range of wavenumber was from 400 cm^{-1} to 4000 cm^{-1}. The spectra of muscovite mica and muscovite mica conditioned with 0.04 g/dm^3 corn starch solution were measured. The mechanism that corn starch on muscovite mica was analyzed according to the infrared spectra. The FT-IR spectrum of muscovite mica powder was measured directly. The following experiment was performed, and the corresponding infrared spectrum was recorded. First, 2 g muscovite mica powder (1.0 μm) was placed in contact with an aqueous solution of a right concentration of corn starch at pH 2.0. The pulp was placed for 1 h after agitation for 3 min. Thirty cm^3 deionized water was added into after pouring out the supernatant, the pulp was placed for 1 h after a 10 min intensive agitation, and repeated the step five times before filtering and drying at room temperature.

Results and discussion

Effect of corn starch on the flotation of muscovite mica

The results for the effect of corn starch on the flotation of muscovite mica at different slurry pH value were shown in Fig. 2. The pulp in the flotation cell was adjusted at different pH value, and $8\cdot10^{-4}$ mol/dm^3 dodecylamine chloride was added into. It showed that muscovite mica powder maintained good flotability in whole pH range when no corn starch solution was added into the flotation cell, and when 0.05 g/dm^3 corn starch solution was added into the cell, the flotability of muscovite mica powder increased with the pH value of the pulp changed from 2 to 6. The biggest gap appeared at the pH 2 of the slurry (Nakazawa et al., 1988). So the strongest inhibitory effect of corn starch on muscovite mica powder appeared at pH 2 of the pulp.

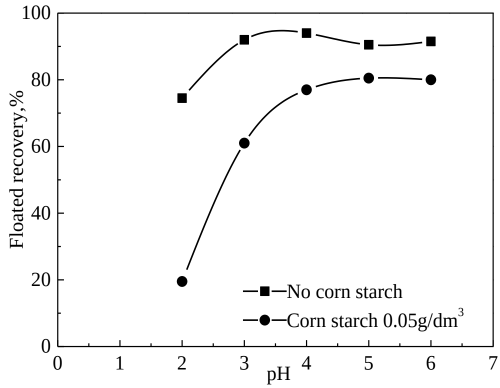

Fig. 2. Results of the effect of corn starch on flotation of muscovite mica at different pH values

The results for the effect of the corn starch dosage on the flotability of muscovite mica at pH 2 and $8\cdot10^{-4}$ mol/dm^3 dodecylamine chloride were presented in Fig. 3. It can be seen that the floated recovery of muscovite mica decreased sharply with the increase of corn starch dosage from 0.02 g/dm^3 to 0.04 g/dm^3. The floated recovery was minimum when the dosage was 0.04 g/dm^3, and it also showed that corn starch had the strongest inhibitory effect on muscovite mica powder when the dosage was 0.04 g/dm^3.

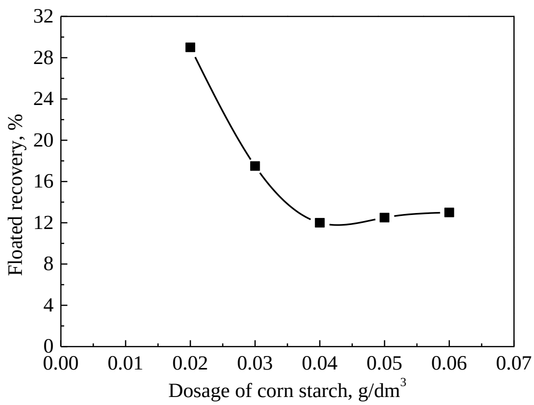

Fig. 3. Effect of corn starch dosage on muscovite mica flotation

Effect of slurry pH value on the adsorption quantity of corn starch

The corn starch concentration in the slurry was measured by a V-1100D spectrophotometer (Mapada, China). The increment of color was proportional to the concentration of corn starch, so ultraviolet spectrophotometer can be used to measure the residual corn starch concentration in slurry (Pavlovic et al., 2003).

The adsorption quantity of corn starch on the surface of muscovite mica powder was calculated based on Eq. 1, and the results were shown in Fig. 4. The results indicated that the adsorption quantity of corn starch on the surface of muscovite mica powder decreased with the increase of pulp pH value from 2 to 6, which coincided exactly with the results of the floated recovery of muscovite mica increased from 19.50 % to 80.02 % at different slurry pH value.

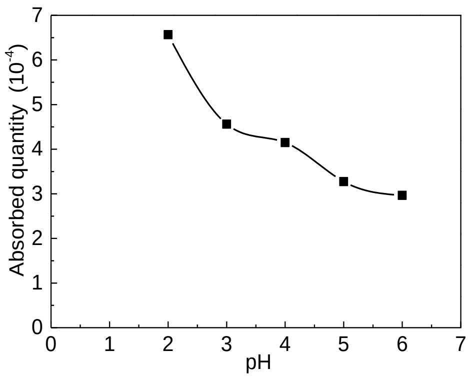

Fig. 4. Adsorption quantity of corn starch
on the surface of muscovite mica at different pH value

Results of zeta-potential measurements

Zeta-potential data has been widely used to interpret the trend of flotation efficiency and the modification of flotation performance caused by the presence of reagents (Zouboulis and Avranas, 2000). The zeta-potential of muscovite mica as a function of pH in the absence and presence of 0.04 g/dm^3 corn starch solution were depicted in Fig. 5. The isoelectric point of muscovite mica was found to be 2, which is consistent with other studies (Brant et al., 2006; Wang et al., 2014). The zeta potential of muscovite mica in water was more negative than in the presence of 0.04 g/dm^3 corn starch solution over the measured pH range of 2~7 (Nakazawa et al., 1988; Nishimura et al., 1992; Nosrati et al., 2012). Both zeta potentials increased with the decrease of pH value from 7 to 2, which coincided exactly with the results of the flotation test. Additionally, the zeta potential of muscovite mica in the presence of 0.04 g/dm^3 corn starch solution decreased in magnitude at the measure range of pH value when compared to that in aqueous solution. Dodecylamine chloride is a cationic collector, which is widely used in the flotation of silicate minerals (Fang et al., 1996; Wang et al., 2014). The dodecylamine cation produced by ionization is absorbed on the surface of negatively charged muscovite mica powder mainly by electrostatic interactions (Atkin et al., 2003), and the adsorption quantity of it decreased with the zeta potential in magnitude of the muscovite mica granule.

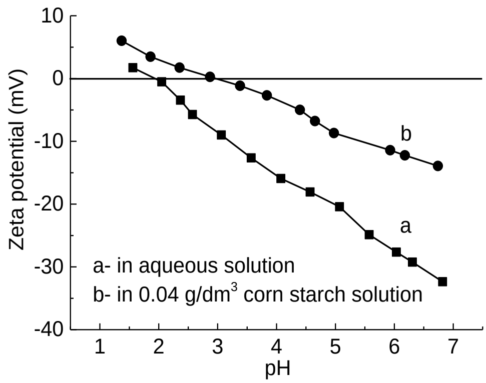

Fig. 5. Zeta-potential of muscovite mica in aqueous solution (a) and 0.04 g/dm^3 corn starch solution (b)

Results of FT-IR spectra

Figure 6 presented the FT-IR spectra of muscovite mica (a) and muscovite mica conditioned with 0.04 g/dm^3 corn starch solution (b). The notable bands at 3620 cm^{-1} and 3440 cm^{-1} were due to the stretching vibration of –OH from Al–OH and Si–OH groups (Temuujin et al., 2001). The characteristic sharp bands at 1070 cm^{-1} and 1027 cm^{-1} in the spectra were attributed to the stretching vibration of Si–O (Andrejkovicova et al., 2008). In addition, weak absorbance peaks at 1080 cm^{-1}, 928 cm^{-1}, 856 cm^{-1} all for vibration of Si–O–Si group too, and 532 cm^{-1}, 475 cm^{-1} for the vibration of Si–O–Al in muscovite mica (Farmer et al., 1964; Hunt et al., 1970).

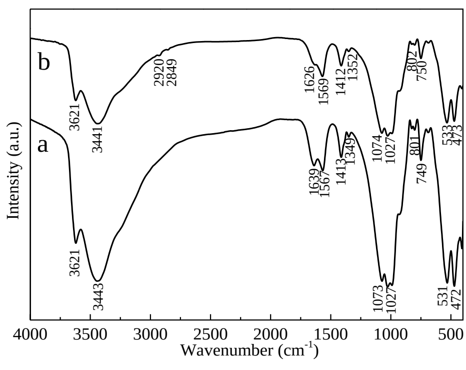

Fig. 6. FT-IR spectra of muscovite mica (a) and muscovite mica conditioned with corn starch (b)

After conditioning of 0.04 g/dm^3 corn starch solution, two weak peaks at 2920 cm^{-1} and 2849 cm^{-1} were obtained and assigned to the stretching vibration of –CH (Liu et al., 2011). Besides, swing absorption peaks of $–CH_2–$ on corn starch appears in 747 cm^{-1} (Pavlovic et al., 2003; Fuerstenau and Pradip, 2005). The spectrum of muscovite mica treated by corn starch solution exhibited characteristic absorption peaks of corn starch, but no band shift was observed, indicating that the adsorption of corn starch on the surface of muscovite mica powder was dominated by physical adsorption (Wang et al., 2014).

Conclusions

The flotation tests and adsorption quantity measurements indicated that the depression effect of corn starch on the surface of muscovite mica powder decreased with the increase of the pulp pH value. The zeta-potential measurements indicated that the corn starch absorbed on the surface of muscovite mica powder can integrally raises the zeta potential of the system at different slurry pH value. Besides, it can be seen from the FT-IR spectra that the corn starch indeed is adsorbed on the surface of muscovite mica powder and no band shift was observed, indicating that physical adsorption played a main role in the process of the adsorption of corn starch on muscovite mica.

Acknowledgments

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