



## Flotation of low-grade bauxite using organosilicon cationic collector and starch depressant



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**Abstract:** The flotation of diasporite and three kinds of silicate minerals, including kaolinite, illite and pyrophyllite, using an organosilicon cationic surfactant (TAS101) as collector and starch as depressant was investigated. The results show that both diasporite and aluminosilicate minerals float readily with organosilicon cationic collector TAS101 at pH values of 4 to 10. Starch has a strong depression effect for diasporite in the alkaline pH region but has little influence on the flotation of aluminosilicate minerals. It is possible to separate diasporite from aluminosilicate minerals using the organosilicon cationic collector and starch depressant. Further studies of bauxite ore flotation were also conducted, and the reverse flotation separation process was adopted. The concentrates with the mass ratio of  $\text{Al}_2\text{O}_3$  to  $\text{SiO}_2$  of 9.58 and  $\text{Al}_2\text{O}_3$  recovery of 83.34% are obtained from natural bauxite ore with the mass ratio of  $\text{Al}_2\text{O}_3$  to  $\text{SiO}_2$  of 6.1 at pH value of 11 using the organosilicon cationic collector and starch depressant.

**Key words:** bauxite; reverse flotation; organosilicon cationic collector; starch depressant

### 1 Introduction

China has abundant bauxite ore resources, however, more than 98% of the bauxite ores are the diasporic type with the characteristics of complex mineral composition, low A/S (mass ratio of  $\text{Al}_2\text{O}_3$  to  $\text{SiO}_2$ ) and difficulty to process. For diasporic bauxite with A/S less than 8, a sintering process or a combination of sintering and Bayer process can be used [1]. However, the sintering process caused environmental damage and wasted energy. Therefore, it needs to increase the A/S of the diasporic ores by flotation method and get a concentrate that can be processed directly by the Bayer process [2,3].

The gangue minerals in bauxites are mainly kaolinite, pyrophyllite and illite [4]. Direct flotation has been shown to be an efficient method for the desilicating of diasporic bauxite [5,6]. However, its disadvantages, such as the difficulty in dewatering concentrate and its high reagent consumption, have restricted its wide application in industry. Therefore, reverse flotation for diasporic-bauxite ore desilicating

has been studied [7–9].

In recent years, many flotation collectors for aluminosilicate minerals in the reverse flotation process, notably, quaternary ammonium salts, *N*-(2-aminoethyl)-dodecanamide, *N*-(2-aminoethyl)-1-naphthalene-acetamide, *N*-dodecyl-1,3-diaminopropanes,  $\gamma$ -alkyl-propylamines, dedecylguanidine sulfate, Gemini quaternary ammonium, dodecyl tertiary amines and alkylguanidine, have been reported effective in collecting aluminosilicate minerals [10–17]. However, most of these collectors are not used in industry due to their deficiencies, such as the excessive amount of foams, high cost, high reagent consumption and low selectivity.

Cationic organosilicon primary ammonium, a new surfactant with bioactivity, is now widely used in the fields of fabric finishing, chemical engineering, pharmaceuticals and agricultural chemicals. However, there is little information regarding the use of this surfactant for mineral flotation. Therefore, in this work, the systematical reverse flotation separation experiments of bauxite ores were conducted in the presence of an organosilicon cationic collector and starch depressant.

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## 2 Experimental

### 2.1 Materials and reagents

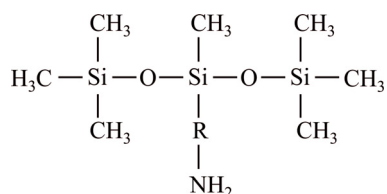
The diasporite, kaolinite, pyrophyllite and illite materials used in the present study were obtained from Xiaoguan of Henan Province, Jiaxian of Henan Province, Qingtian of Zhejiang Province and Ou Hai of Zhejiang Province of China, respectively. They were handpicked and then crushed and ground to less than 0.074 mm in a porcelain mill. The purities of the materials are higher than 95% based on mineralogical analysis, X-ray diffraction (XRD) and chemical analysis.

Diasporic-bauxite ore was obtained from Henan Province, China. This sample with  $\text{Al}_2\text{O}_3$  head assay of 64.32% and  $\text{SiO}_2$  head assay of 10.52% was mainly composed of 65.22% diasporite, 9.8% kaolinite, 6.2% illite, 4.7% pyrophyllite and 0.6% chlorite detected by the XRD analysis and mineralogical analysis, and the A/S of the bauxite was 6.11. The elements analysis results of the bauxite are shown in Table 1.

**Table 1** Elements analysis of bauxite (mass fraction, %)

$\text{Al}_2\text{O}_3$	$\text{SiO}_2$	$\text{Fe}_2\text{O}_3$	$\text{TiO}_2$	$\text{CaO}$	$\text{MgO}$	$\text{K}_2\text{O}$	S
64.32	10.52	6.02	3.05	0.24	0.18	0.92	0.10

$\text{NaCO}_3$ ,  $\text{NaOH}$  and  $\text{HCl}$  were used as pH modifiers and distilled water was used in all experiments. The new collector of organosilicon primary amine (TAS101) has a molecular structural formula as follows:



where R represents  $(\text{CH}_2)_3\text{NH}(\text{CH}_2)_2$ .

### 2.2 Methods

#### 2.2.1 Micro-flotation

Flotation tests were carried out with an XFG5–35 flotation machine with effective cell volume of 40 mL, at the impeller speed fixed at 1800 r/min. 3.0 g mineral samples and suitable amount of distilled water were added. The pH values were adjusted with 0.01 mol/L hydrochloric acid solution and 0.01 mol/L sodium hydroxide solution. After adding the desired amount of collectors, the suspension was agitated for 3 min, and then the pH value was measured. The flotation was sustained for 5 min. The concentrates and tailings were weighed separately after filtration and drying, and the recovery was calculated. The A/S was determined by

silicon–molybdenum blue colorimetry.

#### 2.2.2 Bench scale flotation

The ore samples were crushed to –2 mm, riffled into representative samples of 500 g. For each flotation experiment, the samples were ground in a mild steel rod mill. The flotation tests were performed in an XFD–63 flotation cell (self aeration) whose volume for flotation was 1.5 L using an agitation speed of 1800 r/min. The solid density in the flotation cell was 50% by mass. During the conditioning, depressant, collector and frother were respectively added and conditioned for 5 min to allow reagent adsorption. After the conditioning, the flotation started with the injection of air in the flotation cell, and the air flow rate was kept at 0.1  $\text{Nm}^3/\text{h}$  monitored with a flow meter. Flotation was performed for 12 min and the concentrates was collected.

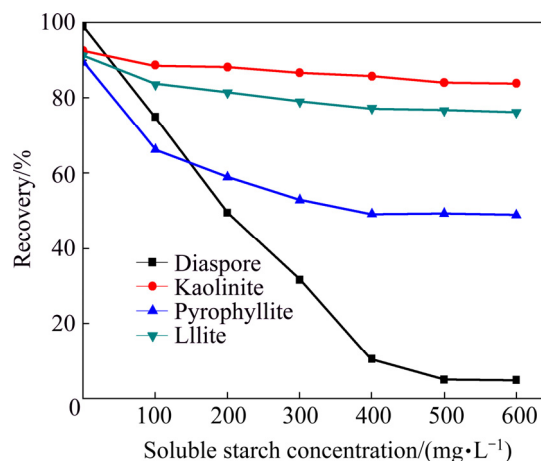
#### 2.2.3 Zeta potential measurements

Isoelectric points (IEP) of mineral samples were determined by measuring the electrophoretic mobility of aqueous dispersions as a function of pH value in a zeta potential meter. For these measurements, 30 mg samples were added into 1 mmol/L  $\text{KNO}_3$  solution and ultrasonicated for 30 min, magnetically stirred for 10 min and the pH value was adjusted using  $\text{HCl}$  or  $\text{KOH}$ . The zeta potential of samples was then measured using a zeta plus potential meter.

## 3 Results and discussion

### 3.1 Role of organosilicon cationic collector and starch in separation of diasporite from aluminosilicates

The effect of starch dosage on the flotation of diasporite and aluminosilicates with  $2 \times 10^{-4}$  mol/L collectors is shown in Fig. 1. It can be seen from Fig. 1 that the flotation of four kinds of minerals is all affected by the presence of starch, but the starch is more effective for the depression of diasporite than that of kaolinite, illite



**Fig. 1** Effect of starch dosage on flotation of diasporite and aluminosilicates (Collector concentration:  $2 \times 10^{-4}$  mol/L; pH=10)

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