Available online at www.sciencedirect.com
ScienceDirect
Trans. Nonferrous Met. Soc. China 25(2015) 1279−1285
Transactions of Nonferrous Metals Society of China
www.tnmsc.cn

Flotation separation of andalusite from quartz using sodium petroleum sulfonate as collector

Hai-ling ZHU, Hai-bo DENG, Chen CHEN

School of Minerals Processing and Bioengineering, Central South University, Changsha 410083, China

Received 5 May 2014; accepted 24 June 2014

Abstract: The floatability of andalusite and quartz was studied using sodium petroleum sulfonate as collector, being successfully applied in the real ore separation. The collecting performance on minerals was interpreted by means of zeta potential measurement and infrared spectroscopic analysis. The single mineral experiments showed that andalusite got good floatability in acidic pH region while quartz exhibited very poor floatability in the whole pH range. At pH 3, the presence of Fe^{3+} obviously activated quartz, causing the identical flotation behavior of the two minerals, and calcium lignosulphonate exhibited good selective inhibition to quartz. The real ore test results showed that andalusite concentrate with 53.46% Al_2O_3 and quartz concentrate with 92.74% SiO_2 were obtained. The zeta potential and infrared spectroscopic analysis results indicated that chemical adsorption occurred between sodium petroleum sulfonate and andalusite.

Key words: flotation separation; andalusite; quartz; sodium petroleum sulfonate

1 Introduction

Andalusite is a kind of aluminosilicate minerals, which belongs to three different forms of kyanite minerals together with kyanite and sillimanite. After being heated to 1350 °C at normal pressure, andalusite begins to transform to acicular mullite in parallel with the original crystal and form a strong mullite network, thereby, it has good characteristics such as strong fire resistance and slag resistance, high mechanical strength and chemical stability [1,2]. Consequently, andalusite is a superior material to produce refractory materials, and it has been widely used in spaceflight, metallurgy, ship and other industrial circles [3,4]. Andalusite to be used in the refractory industry should be separated from impurities such as Fe_2O_3, TiO_2, CaO, MgO, Na_2O and K_2O as much as possible. The content of Al_2O_3 is required to be above 60% in high-grade andalusite, and 52%−54% in low-grade andalusite. So, concentration process is necessary for industrial needs.

There are many methods for andalusite beneficiation such as hand sorting, gravity separation, magnetic separation and flotation. And the suitable method is adopted based on the mineral properties. For andalusite ore containing larger single crystals, process of gravity separation−magnetic separation can be used to obtain coarse concentrate. Flotation is the most common and effective method for fine andalusite flotation. Prior to andalusite flotation, adequate desliming and iron removal are necessary in order to decrease reagent consumption and improve flotation results. In addition, cationic collectors are used for flotation of gangue minerals such as micas, kaolinite and garnet which are easy to float and influence the concentrate grade due to good floatability. Then, andalusite is separated from the gangue minerals, mainly quartz.

The flotation process mainly includes alkaline process and acid process, which is related to the mineral surface potential and reagent system. In alkaline process, the optimum pH is 8−10, which is adjusted by NaOH or Na_2CO_3, and the carboxylic acid and its salt are used as collectors. However, the optimum pH 3−4 is mainly adjusted by H_2SO_4, and the sulfonate type collector is employed for the flotation of andalusite in acid process. Sodium silicate, lactic acid, citric acid, carboxymethocel and their combinations can be used for depressing gangue minerals.

There are many successful practices of andalusite beneficiation. YANG et al [5] studied the separation of coarse andalusite (0.5−1 mm) using *d*150 mm heavy medium cyclones, and an acceptable coarse concentrate

Corresponding author: Hai-bo DENG; Tel: +86-731-88710804; E-mail: denghaibocsu@163.com
DOI: 10.1016/S1003-6326(15)63726-8

with a grade of 58.78% Al_2O_3 and a recovery of 29.7% was obtained. LI and LI [6] presented the research achievements and application of DMG electromagnetic pulsating high gradient magnetic separator in iron removal from andalusite. ZHOU and ZHANG [7] found that a pre-treatment by desliming and pre-floating (to remove carbonaceous species) followed by flotation produced a concentrate assaying 56.5% Al_2O_3 at an aluminum recovery of 65.7%.

In this work, the separation of andalusite from quartz using sodium petroleum sulfonate as collector was investigated. In the molecular structure of sodium petroleum sulfonate, a highly-hydrophilic sulfo-group is connected with alkyl, the structural formula is RSO_3Na, R is a linear aliphatic alkyl with an average of 14−18 carbon atoms.

2 Experimental

2.1 Materials

The pure andalusite and quartz samples were taken from Xinjiang Uyghui Autonomous Region, China. The samples were handpicked, ground in porcelain mill and then sieved to collect 0.038−0.074 mm fraction for the flotation tests. The chemical analyses showed that the grade of Al_2O_3 was 59%, the purity of andalusite was above 95%, and the main impurity was quartz. The purity of quartz was 99.8%, the sample was immersed in diluted hydrochloric acid (around 10%) due to the presence of iron, then washed repeatedly with distilled water, and dried for later use.

The multi-element analysis results and the aluminum phase analysis results of the real ore sample are shown in Tables 1 and 2, respectively.

Table 1 Multi-element analysis results of real ore sample

Composition	Al_2O_3	TiO_2	SiO_2	TFe	Mg
Mass fraction/%	18.47	0.65	68.28	2.80	0.085
Composition	Ca	Mn	S	P	Ignition loss
Mass fraction/%	0.315	0.017	0.71	0.76	2.76

Table 2 Aluminum phase analysis results of real ore samples

Phase	Mass fraction of content/%	Occupancy/%
Al_2O_3 in andalusite	12.21	66.11
Al_2O_3 in other minerals	6.26	33.89
Total Al_2O_3	18.47	100.00

It can be seen that the main chemical compositions of the real ore samples are SiO_2 and Al_2O_3, followed by Fe, and a little TiO_2. Aluminum in the ore is not all distributed in andalusite, and the Al_2O_3 content in andalusite is 12.21%, accounting for 66.11%.

2.2 Flotation tests

Flotation tests of single minerals were performed on a 40 mL flotation machine at a constant impeller speed of 1650 r/min. Experiments were carried out at varying pH and reagent concentrations. For each test, 2 g mineral samples were placed into the flotation cell, decent amount of distilled water was added and stirred for 2 min. Then, reagents were successively added to the pulp with each conditioning time of 3 min according to the experiment requirements, and the flotation was performed for 4 min. The floating and non-floating fractions were separately dewatered, dried and weighed for assessment.

Flotation tests on the real ore sample were carried out in a series of 0.5−1.5 L flotation machine. For each test, 500 g samples were used. A desirable sulfuric acid, calcium lignosulphonate and sodium petroleum sulfonate were added and stirred for 3 min, respectively. The concentrate and tailing were separately dried, weighed and sampled to analyze the contents of Al_2O_3 and SiO_2 to calculate the yield and recovery.

2.3 Zeta potential measurement

Zeta potential was measured with a zeta potential analyzer (DELSA−440SX, USA). The mineral suspensions with 0.01% solid of size less than 3 μm were dispersed in a beaker by ultrasonic cleaning, and transferred to the rectangular capillary cell of the instrument after treatment with relevant reagents.

2.4 Infrared spectroscopic analysis

To investigate the mechanism between collector and minerals, the infrared spectra were obtained with a Fourier transform infrared spectrophotometer (740−FTIR, USA). The mineral samples of size less than 2 μm were treated with reagents in high concentration, dewatered, and washed 3 times using distilled water with the same pH value, and then dried in air. After that, the samples were pressed into flake in a specialized mould, and the flaky samples were placed in sample stand to be analyzed.

3 Results and discussion

3.1 Flotation behavior of single mineral

3.1.1 Effect of collector

The effect of pH on the flotation recovery of andalusite and quartz using sodium petroleum sulfonate as collector is shown in Fig. 1. It is shown that the andalusite exhibits good floatability at acidic pH values and the flotation recovery decreases with the increase of pH value. By contrast, quartz keeps very low flotation recovery at pH values of 2–12.