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The effect of a new polysaccharide on the depression of talc and the flotation of a nickel–copper sulfide ore

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ABSTRACT

The effect of the depressant galactomannan (KGM) on the depression of talc and the flotation of a nickel–copper sulfide ore have been investigated through microflotation, batch flotation and industrial flotation tests, zeta potential and infrared spectrum measurements. The flotation results indicated that KGM had a straining influence on the depression of talc while had little effect on nickel minerals flotation. Compared with the depressant carboxymethyl cellulose (CMC) and guar gum, the KGM increased the nickel recovery dramatically, it not only negated the need for a talc removal process, but also achieved a significant decrease in the depressant consumption by half. Zeta-potential and infrared spectrum measurements illustrated that chemical adsorption was seen between KGM and talc, and a possible weak physical adsorption was seen between KGM and pentlandite. This was the reason why KGM had high depression selectivity for talc and little depression effect on nickel minerals.

1. Introduction

Talc is the most common hydrophobic mineral encountered in complex nickel sulfide ore and in the ore of platinum group metals (Bremmell et al., 2005; Chen et al., 1999a, 1999b; Engel et al., 1997; Pietrobon et al., 1997; Senior and Thomas, 1997; Wiese et al., 2007; Witney and Yan, 1997). The presence of hydrophobic gangue represents a major problem in treatment of both nickel and nickel–copper sulfide ores. Being naturally hydrophobic, in nickel sulfide processing, talc easily reports to flotation concentrates, thus reducing concentrate grade and causing downstream processing problems as well as increased smelting costs (Beattie et al., 2006a, 2006b; Feng et al., 2012a; Steenberg and Harris, 1984; Shortridge et al., 2000). The depression of talc and other magnesia-bearing minerals has therefore been the focus of a great deal of research.

Depressants play an important role in affecting selective separation of nickel minerals from ores by flotation. Polysaccharides and their derivatives are depressants for talc and other magnesia-bearing minerals. There are numerous reports (Feng et al., 2012b; Hicyilmaz et al., 2004; Khraisheh et al., 2005; McFadzean et al., 2011; Rath et al., 1997; Morris et al., 2002; Shortridge et al., 2000) on the application of polymer (carboxymethyl cellulose, guar gum and other polysaccharide polymers) as a depressant for talc and other magnesia-bearing minerals present as impurities in various sulfide ores. Meanwhile, guar gum has been one of the most widely used in the processing of many nickel sulfide ores to depress hydrophobic gangue minerals (Leung et al., 2011; McFadzean et al., 2011; Senior et al., 1995; Wang et al., 2005; Wiese et al., 2007). However, this tends to force guar gum pricing to be market related and it usually suffered the disadvantage of limited availability and high cost (Jiang et al., 2012). Therefore, there is a demand to develop more selective, cheap and high performance depressants for separation of nickel from magnesia-bearing minerals.

Technological innovations have been made and the introduction of amorphophallus products into the minerals processing industry have been successful. Galactomannan (KGM) is made from the root of the amorphophallus or trigonella plants and is a new high molecular weight polysaccharide, used as a powerful water-soluble dietary fiber supplement in food additives, medicine, chemicals, etc. (Zhou et al., 2012). Amorphophallus and trigonella plants are widely grown in China Southern and Japan (Jiang et al., 2012). Thus, KGM was the advantage of being an abundant resource and low in price compared to guar gum. KGM used as a commercial depressant for the flotation separation of nickel–copper minerals from Ni/Cu sulfide ores has not been reported, and the theoretical investigation on the adsorption mechanism

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between depressant KGM and minerals has not been studied previously.

Thus in the present study, the galactomannan (KGM) was developed as a depressant by the authors to depress talc effectively, and the depressing performance of KGM was compared with guar gum and carboxymethyl cellulose (CMC) in the flotation of nickel–copper minerals from a low-grade Ni/Cu sulfide ore which contains talc, in the Danba Nickel–copper Mine. In addition, the adsorption mechanisms of KGM on pentlandite and talc were investigated by zeta potential measurements and infrared spectrum analysis.

2. Experimental

2.1. Samples and reagents

2.1.1. Samples

The pure mineral samples of pentlandite and talc were obtained from the Danba Nickel–copper Mine, Sichuan Province, China. The samples were crushed, handpicked and then dry-ground with a porcelain ball mill and dry-sieved to obtain different size fractions. The $(-150+74)$ μm fraction was used for the flotation tests. Chemical analysis and X-ray powder diffraction data confirmed that the purity of pentlandite was 91.5% and talc purity was 95.6%.

The low-grade Ni/Cu sulfide ore (containing talc) for batch flotation and industrial flotation tests was also from the Danba Nickel–copper Mine. The multi-elemental chemical analysis of the ore was conducted by Atomic Adsorption Spectroscopy (AAS) and Inductively Coupled Plasma Optical Emission Spectrometer (ICP-OES), and the analysis results are shown in Table 1. As shown in Table 1, the minerals contained 0.36% Cu, 0.78% Ni, 28.91% MgO, 38.15% SiO_2 and 4.98% Al_2O_3, and also contained many platinum group metals. The mineralogical data confirmed that in this Ni/Cu sulfide ore, nickel and copper mainly existed in the form of pentlandite and chalcopyrite respectively. Meanwhile, the predominant gangue minerals were easy-floating and easy-sliming magnesium silicate, such as talc and serpentine, especially for talc, it accounted for 35–40% in the total minerals.

2.1.2. Reagents

The depressant galactomannan [KGM, structure $(C_6H_{10}O_5)_n$, >92% purity] was extracted and purified from fenugreek powder. The viscosity of aqueous solutions of 1% (by weight) KGM was 25–30 Pa s. It was supplied by the Institute of Multipurpose Utilization of Mineral Resources Flotation Reagents Limited Company.

In the microflotation tests, KGM was used as depressant, sodium isobutyl xanthate (SIBX) was used as collector, methyl isobutyl carbinol (MIBC) was used as frother, and hydrochloric acid (HCl) and sodium hydroxide (NaOH) were used as pH regulators. All reagents used in microflotation tests were of analytical grade. Deionized double distilled water was used for microflotation, zeta-potential and infrared spectra experiments.

In batch flotation tests, KGM, guar gum, carboxymethyl cellulose (CMC), dextrin, lime and sodium fluorosilicate were used as depressant, oxalic acid and sulfurous acid were used as pH regulators. PAX, ammonium dibutyl dithiophosphate (ABDTP) and ethyl thiocyanate were used as collector. Activated carbon was used as adsorbent, and MIBC was used as frother. All reagents (except KGM) used in batch flotation were of industrial grade. Tap water was used for batch flotation tests.

2.2. Experiments

2.2.1. Microflotation flotation tests

A flotation machine of XFG-1600 type (mechanical agitation) with the volume of 40 ml was used in microflotation tests. The impeller speed was fixed at 1800 rpm. The mineral suspension was prepared by adding 2.0 g of single mineral to 40 ml of solutions in single mineral flotation tests, and adding 1.0 g each of pentlandite and talc to 40 ml of solutions in mixed minerals flotation. The mineral surfaces were cleaned by using ultrasound cleaner. The pH of the mineral suspension was adjusted to the desired operating value by adding HCl or NaOH stock solutions. The general reagent addition scheme involved depressant, collector and then frother addition with each stage having a 2 min conditioning period prior to the next reagent addition. Flotation concentrates were then collected for a total of 5 min. The floated and unfloated particles were collected, filtered and dried. In single mineral flotation, the recovery was calculated based on solid weight distributions between the two products. In mixed minerals flotation, the flotation recovery was assessed by chemical analysis of the two products. In order to assess the accuracy of flotation tests, the errors of the recovery were found to be within 2.0% after at least five tests at each condition, and the average values are reported.

2.2.2. Batch flotation tests

In the batch flotation tests, the ore (1 kg, crushed to -3 mm during sampling) was ground to 76.7% passing 74 μm in a closed steel XMQ-240 × 90 mm ball mill at a pulp density of 66% by weight. The bench-scale flotation tests were performed in XFD-63 flotation cell (self aeration), 3000 ml for rougher flotation and 1000 ml for cleaner flotation, and 500 ml for flotation separation of nickel/copper minerals, respectively. The Ni/Cu bulk flotation used 1 kg ore to obtain a Ni/Cu bulk concentrates, then two Ni/Cu bulk concentrates were mixed together to regrind and separate copper minerals from the bulk concentrates. After wet grinding, the desired amounts of reagents were added to the slurry while agitating at about 1500 rpm and the slurry was conditioned for 6 min. Air was then fed and the froth flotation was continued for 5 min during which a rougher concentrate was collected. The rougher concentrates and tailings were filtered, dried, weighted, sampled and assayed for copper and nickel. To assess the accuracy of flotation experiments, the calculated grade of feed was compared with the head assay. If the calculated nickel grade of feed was not in the range of 0.78 ± 0.01%, then the concentrates and tailings were re-assayed for nickel, or the flotation tests were redone. The flotation flowsheet of the bench-scale tests is described in Fig. 1. The experimental system used KGM as depressant (the total dosage of KGM in locked cycle test was 450 g/t), and the comparative system used guar gum as depressant (the total dosage of guar gum in locked cycle test was about 950 g/t).

2.2.3. Industrial tests

The industrial tests were performed in the Mineral Processing Plant at the Danba Nickel–copper Mine. The experimental system M1 used KGM as depressant in the flotation. The flotation

Table 1
The results of multi-elemental chemical analysis of the ore for batch flotation and industrial tests.

Element	Cu (%)	Ni (%)	MgO (%)	SiO_2 (%)	Fe_2O_3 (%)	CaO (%)	Al_2O_3 (%)	Au (g/t)	Ag (g/t)	Pt (g/t)	Pd (g/t)
Grade	0.36	0.78	28.91	38.15	17.26	4.69	4.98	0.08	5.31	0.19	0.56