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Selective separation of pyrite from chalcopyrite and arsenopyrite by biomodulation using *Acidithiobacillus ferrooxidans*

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Abstract

This paper discusses the selective depression of pyrite from chalcopyrite and arsenopyrite by biomodulation using *Acidithiobacillus ferrooxidans* under natural conditions of pH. The effect of bacteria–mineral interaction on the surface charge of mineral and bacterial cell was studied by microelectrophoresis. Adhesion experiments were conducted to establish the relationship between cell adhesion to specific minerals and the electrokinetic behaviour of the minerals subsequent to interaction with cells. Effect of bacterial interaction on the xanthate-induced flotation of all the minerals was assessed. Adhesion of *A. ferrooxidans* on pyrite was rapid and tenacious and subsequent to interaction with cells, pyrite remained hydrophilic even in presence of xanthate collector. The collector, on the other hand, was able to render good flotability to chalcopyrite even after interaction with bacterial cells. Copper activated arsenopyrite was able to retain its hydrophobicity in presence of cells due to poor attachment kinetics of cells to the mineral surface. Thus, by suitably conditioning with the cells and collector, it was possible to effectively depress pyrite from chalcopyrite and arsenopyrite.

Keywords: *Acidithiobacillus ferrooxidans*; pyrite; chalcopyrite; arsenopyrite; biomodulation; selective flotation

1. Introduction

Separation of pyrite from other associated metal sulphides is desirable for the economical extraction of their valuable metals. Chalcopyrite and arsenopyrite are often associated with pyrite and selective depression of the pyrite from these would prove economically beneficial for further extraction. Separation of pyrite from chalcopyrite is conventionally achieved by selective depression of pyrite using depressants like cyanide under alkaline conditions. On the other hand, separation of pyrite from arsenopyrite has been a problem due to their similar flotation behaviour with sulphidic collectors. Conventional techniques for separation of pyrite from either chalcopyrite or arsenopyrite utilize depressants like cyanide or oxidizing agents like permanganates and magnesia–ammonia mixture for selective oxidation of arsen-

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opyrite (Randol, 1992; Yen and Tajadod, 1999). Thus, there is still a need for less-expensive and environmentally benign reagents.

The utility of microorganisms in selective flotation or depression of sulphides and oxides has been previously reported (Yelloji Rao et al., 1992; Deo and Natarajan, 1998; Santhiya et al., 2000; Patra and Natarajan, 2003). However, no significant research has been reported on the separation of pyrite from associated ferrous sulphides. Recently, Sharma et al. (1999) have studied the effect of bacterial conditioning on the behaviour of pyrite and chalcopyrite. In our previous study (Chandraprabha et al., 2004), we were able to achieve selective separation of pyrite from a mixture of pyrite and chalcopyrite by collector interaction and biomodulation using *Acidithiobacillus ferrooxidans*.

In the present study, selective separation of pyrite from a mixture of chalcopyrite and arsenopyrite by biomodulation and collector interaction has been investigated in detail.

2. Materials and methods

2.1. Minerals

Arsenopyrite was obtained from Wards Scientific, USA, pyrite from Alminrock Indser Fabricks, India, and chalcopyrite from Gregory, Bottley and Lloyd, UK as pure handpicked mineral samples. The mineral samples were dry ground in a porcelain ball mill and dry sieved to obtain different size fractions. The −106+75-μm fraction was used for flotation studies. The −37-μm fraction was further ground in a Retsch mortar grinder. The particle size analysis of this sample was carried out using a Malvern Mastersizer 3000-model and the mean size was found to be ≈5 μm. This fraction was used for adsorption and electrokinetic studies. The minerals were stored in a desiccator under nitrogen atmosphere. The surface area was estimated by BET nitrogen specific surface area method and was found to be 1.26 m^2/g for pyrite, 1.61 m^2/g for chalcopyrite and 1.77 m^2/g for arsenopyrite respectively. Purity of the mineral samples were ascertained by mineralogical studies and X-ray diffraction using a JDX-8030 X-ray diffractometer system. The purity of the mineral samples was 99.9% for pyrite, 99.4% for chalcopyrite and 98.7% for arsenopyrite, respectively.

2.2. Microorganism and preparation of cell pellet

The bacterial culture used was a strain of *A. ferrooxidans* that was isolated from Hutti Gold Mines (HGML) and is referred to as TfH6. The purity was ascertained by the procedure outlined by Karavaiko (1988). The bacteria were cultured in sterile 9K medium developed by Silverman and Lundgren (1959). The bacterial count was monitored by direct counting under a Leitz phase contrast microscope (Labrolux K Wild MPS12) using a Petroff Hausser counter.

The grown culture was initially filtered through Whatman 42 filter paper to remove the precipitates. The filtrate was centrifuged at 10,000 rpm for 20 min in a Sorvall RC-5B refrigerated high-speed centrifuge at 5 °C to obtain the cell pellet. The pellet obtained was resuspended in pH 2 H_2SO_4 solution and then centrifuged as before to obtain metabolite-free cells.

2.3. Adsorption studies

The cell pellet from a culture of known cell concentration was suspended in 100 ml 10^{-3} M KCl solution at the desired pH in 250-ml standard Erlenmeyer flask. The mineral sample (1 g) was pulped to the cell suspension and the slurry obtained was agitated on a rotary shaker at 200 rpm for 30 min for equilibration. After equilibration, the slurry was vortex mixed for 1 min to remove loosely held cells, centrifuged at 2000 rpm for 5 min to settle the mineral particles and the cell number of the supernatant was recorded. For experiments on adhesion kinetics, the above procedure was repeated at regular intervals and the cell data with respect to time recorded.

2.4. Electrokinetic studies

The electrophoretic mobilities of the mineral samples before and after interaction with the bacterial cells were determined using a Malvern Zetasizer 3000 instrument. KCl solution (10^{-3} M)