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Water quality – A comparative study between moncheite and pentlandite in mixture with pyroxene

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ABSTRACT

This study examines the surface alteration and flotation behaviour of synthetic moncheite and pentlandite, both in mixture with pyroxene, in the presence of process water containing various ionic concentrations. Ionic strength was also investigated using sodium chloride to modify the water ion concentration. It is proposed that ions found in process waters as well as dissolution products from the minerals present passivate the mineral surfaces and inhibit collector adsorption which affects the floatability of moncheite, pentlandite and pyroxene. A comparison is drawn between the PGE, BMS and gangue minerals.

ToF-SIMS analyses were used to characterise the mineral surface as well as the extent of surface alteration. Microflotation was used to determine the hydrophobicity of the synthetic minerals.

The results have shown that there seems to be a synergistic effect between an ionic strength of $\geqslant 0.1$ and ion concentration in process water. However, the ions in the process water play a more significant role compared to ionic strength in terms of mineral surface alteration and floatability of the mineral mixtures evaluated. The dissolution products from the valuable minerals affected the flotation response of pyroxene.

1. Introduction

It is well established that the quality of process water has a significant influence on flotation recovery and selectivity, especially when the water is recycled, and the concentration of the ions increases (Levay et al, 2001). Many in-house studies have been carried out to determine which ions play a detrimental role during the Platinum Group Element (PGE) mineral flotation and to possibly determine threshold values. The results obtained do not specifically identify detrimental ions but show that waters with varying cation and anion concentrations result in varying flotation responses. Currently only nitrate and ammonium have been identified as problem ions which negatively affect the flotation response of the PGE minerals. The fundamental studies that have been conducted have shown that certain ions, viz. calcium, play a detrimental role in the flotation of pentlandite and pyroxene mixtures when compared to the results obtained using a simple electrolyte (Malysiak, 2003).

During the study described in this paper, synthetic water, containing key ions typically found in process water, was prepared in order to determine the effect of varying the concentration of cations and anions on the floatability and selectivity of moncheite-pyroxene mixtures and pentlandite-pyroxene in the presence and absence of SIBX at pH 9. Ionic strength was also varied using ions which have a minimal effect on flotation to de-couple ionic strength from the cations and anions present in solution. Microflotation and ToF-SIMS (Time of Flight Secondary Ion Mass Spectrometry) were used as tools in determining the effect of surface alteration on the flotation response.

The objective of the study is to obtain a fundamental understanding of the floatability of moncheite -pyroxene and pentlandite -pyroxene mixtures by measuring the effect of parameters such as collector adsorption, ionic activation, and the distribution of ions on the mineral surfaces and relating these to the microflotation behaviour of the samples.

2. Experimental methods

2.1. Minerals

Natural pyroxene, synthetic moncheite $[PtPd(BiTe)_2]$ and synthetic pentlandite $[(Fe,Ni)_9S_8]$ were used during the study. Natural pyroxene from Amandelbult Section was crushed to 2 mm and selected by hand picking. Moncheite and pentlandite were synthesised at Anglo American Research (AAR) using methods developed by Johnson Matthey with slight modifications to produce a homogeneous product.

Moncheite was prepared by weighing stoichiometric amounts of the pure material (platinum and palladium sponge and bismuth

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and tellurium powder) into a silica tube which was evacuated overnight, sealed and thermally treated. The thermal treatment involved heating the ampoule to 1150 °C and then linear cooling to 480 °C, keeping at that temperature for 4 weeks then switching off the furnace and allowing cooling naturally to ambient temperature. Pentlandite was prepared by weighing stoichiometric amounts of reduced iron (11 g) and reduced nickel (11.86 g) which were mixed with sulphur flake (11.41 g) and transferred to a quartz ampoule and evacuated overnight, sealed ampoule and stage heated in a furnace to 1150 °C for 2 h then cooled to ambient temperature. The final products were sent for mineralogical analysis to verify the homogeneity of the sample.

Mineral samples were stored under argon in a freezer and freshly ground in an agate mortar just prior to each experiment. The products were screened to obtain size fractions of +25–53 μm for pentlandite or moncheite and +53–106 μm for pyroxene; these fractions were combined in a 1:1 ratio of pentlandite or moncheite to pyroxene for both the microflotation and surface analysis testwork.

2.2. Reagents

Purified sodium isobutyl xanthate (SIBX) powder was obtained from SENMIN and used as the collector at a dosage of 5.00E-05 M. Other chemicals were of analytical grade quality. Sodium carbonate (0.1 M) and hydrochloric acid (0.1 M) were used for pH adjustment.

2.3. Synthetic water composition

During the study, deionised water (DI) and synthetic process water, which contains similar amounts of key ions typically found in process water used on PGM concentrators, was used for the microflotation tests, XPS and ToF-SIMS analyses. Variations in the concentration of the cations and anions (synthetic water, 5× synthetic water and 10× synthetic water) were also evaluated (Table 1). Table 2 shows the ionic strength trials where ionic strength was varied using sodium chloride solutions with a concentration of 2.5 g/L and 25 g/L.

2.4. Time of Flight Secondary Ion Mass Spectrometry (ToF-SIMS)

Surface analysis of the minerals was carried out using a PHI TRIFT IV ToF-SIMS instrument operating in the static SIMS regime. A pulsed primary ion beam bombards the sample surface, causing the emission of atomic and molecular secondary ions. A small percentage of the secondary ions are charged and can therefore be extracted by an electric field into a mass spectrometer. The mass spectra are recorded by measuring the time difference between pulsing the primary ion gun and the arrival of secondary ions on a fast dual microchannelplate detector at the spectrometer, by means of a multistop time-to-digital converter. ToF-SIMS analysis was carried out on stirred trial products (samples were conditioned in the desired solution at pH 9 for 1 minute prior to reagent addition; a 2 min conditioning period was used for SIBX). The samples were filtered and washed with deionised water (conductivity 0.7 μm S cm^{-1}), adjusted to pH 9, to remove any physically attached ions. All samples were dried in an argon atmosphere at ambient temperature, screened and stored under argon in a freezer.

Table 1
Synthetic water-Cation and anion concentrations.

Cation/anion	Deionised water	Synthetic water (ppm)	5× Synthetic water (ppm)	10× Synthetic water
Ca^{2+}	29	80	400	800
Mg^{2+}	33	80	400	800
Na^{+}	87	135	675	1350
Cl^{-}	143	270	1350	2700
SO_4^{2-}	110	250	1250	2500
NO_3^{-}	88	135	675	1350
CO_3^{2-}	16	40	200	400
TDS	506	990	4950	9900
Ionic strength	0.012	0.025	0.130	0.250

Table 2
Synthetic water – Variations in ionic strength.

Cation/anion	2.5 g/L NaCl (ppm)	25 g/L NaCl (ppm)
Na^{+}	984	9835
Cl^{-}	1516	15,165
TDS	2500	25,000
Ionic strength	0.043	0.430

Throughout the study a 30 kV, 100 μm-Au_1 bunched cluster beam with charge compensation was used. Five areas (300 × 300 μm) of each sample were imaged and analysed for K, Si, Na, Ca, Mg, Al, Ni, Fe, and Cu during positive ion analysis and S, O, OH, and xanthate during negative ion analysis. The data obtained were evaluated using Statistica. The intensities obtained are normalised for the elements of interest and presented as a percent normalised yield.

2.5. Microflotation testwork

A microflotation cell (volume 250 cm^3) was used to determine the flotation response of moncheite-pyroxene and pentlandite-pyroxene mixtures. The cell consists of a conical tapered cylindrical tube with air introduced through a needle at the base of the cell (Wesseldijk et al., 1999). Mineral loaded bubbles rise through the cell and are deflected off the cone at the top of the cell, after which they burst, resulting in the minerals dropping into the concentrate launder. The testwork involved taking a 2 g sample, 1 g of moncheite or pentlandite (+25–53 μm) and 1 g of pyroxene (+53–106 μm), which was added to 250 ml of the required solution, which had been adjusted to pH 9. The desired pH was maintained throughout the flotation by adjusting with either sodium carbonate or hydrochloric acid. Concentrates were collected at time intervals of 2, 5, and 10 min. The floated and non-floated fractions were allowed to dry in air, screened and weighed. The conditioning period for SIBX was 2 min.

3. Results

The figures in this section show data for either moncheite/pentlandite or pyroxene on their own but the interpretation should always consider that the testwork was carried out as moncheite–pyroxene and pentlandite-pyroxene mixtures and not as single minerals. Therefore dissolution products from either moncheite/pentlandite or pyroxene may contribute to the surface alteration of the minerals in the system and affect floatability.

3.1. Surface analysis

3.1.1. ToF-SIMS analyses

ToF-SIMS analysis is a well-established technique in determining the occurrence of atomic/molecular species on the surface of mineral samples. It must be noted that the ToF-SIMS values are relative and not absolute.

Figs. 1 and 2 shows the calcium ions normalised yield obtained for moncheite and pyroxene, respectively. It is clear from the figure