Effect of Collector Type and Blends on Mixed Pyrite and Arsenopyrite Flotation

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Abstract

Sulfhydryl collectors have received wide applications in sulphide value mineral flotation. Blends of this group of collectors have shown the existence of synergism in collecting action when utilized in flotation. In this study, sodium isobutyl xanthate and sodium alkyl dithiophosphates at different mixing ratios are employed in flotation. Results for single mineral flotation show that better flotation response was achieved for collector admixtures compared with singular uses. The highest recovery of 87.78% and 67.74% respectively for pyrite and arsenopyrite was achieved with a blend ratio of 20:80 SIBX to DTP.

Keywords: Dithiophosphate, Dimer, Bulk flotation

1 Introduction

Gold, a globally traded commodity, has played significant role in the civilization of mankind (Paul *et al*., 2019). The varied use of the metal in different scientific fields and overwhelming demand are the basis for efficient and sustainable production from its ores. Progressive depletion of 'easy to treat' ores have made refractory gold an important source of gold produced and currently and accounts for nearly a third of the world's total gold production (Yang *et al*., 2013). Gold in refractory ores are preferentially associated with pyrite and arsenopyrite (Arehart *et al.,* 1993, McCarthy *et al.,* 2018, Zhang *et al*., 2016, Asamoah *et al.,* 2019b, Asamoah *et al*., 2019a). To produce an enriched feed for downstream processing, froth flotation is often used to produce a concentrate of gold-bearing pyrite, arsenian pyrite and arsenopyrite (Shean and Cilliers 2011).

However, conditions such as oxidation of the mineral in aqueous solution and resultant increase in hydrophilic species on the minerals surfaces lowers flotation recovery and require higher reagent consumptions to restore floatability (Dong *et al*., 2019). Thiol collectors; xanthates, dithiophosphates and dithiocarbamate have been investigated in the flotation of these sulphides (Dunne 2005, Chanturiya *et al*., 1998). Although xanthates are widely used, a synergistic effect have been reported elsewhere to exists between collector admixtures (Lotter and Bradshaw 2010). Improvement in rate of flotation (Adkins and Pearse 1992), improvement in coarse particle recovery (Plaksin and Glembockii 1954), reduction in dosage requirement (Lotter and Bradshaw 2010) and high recoveries for optimum ratio of constituents (Valdiviezo and Oliveira 1993, Deng *et al*., 2010) are but a few of their confirmed benefits. Undoubtedly, the aforementioned benefits improve overall flotation recovery and reduces loss of values to tailings.

This paper is aimed at investigating the effect of collector type and blends on flotation performance and pyrite-arsenopyrite selectivity. This research forms part of a study focused on selectively separating high gold bearing arsenopyrite and arsenian pyrite from barren pyrite.

2 Materials and Methods Used
2.1 Materials

Model pyrite and arsenopyrite samples were obtained from GeoDiscoveries in Australia. About 1 kg each of the 3 mm samples was crushed and dry-groud to a P_{80} of 425 μm, split to 50 g lots and stored.

The samples were further ground using an agate mortar and pestle to obtain a -75+38 μm for the flotation study. Sodium Isobutyl Xanthate (SIBX) and methyl isobutyl carbonyl (MIBC) used for flotation were industry grade with purity greater than 96%. Sodium diisobutyl dithiophosphate (DTP) was obtained from the Solvay Group with 60% active ingredients. Analytical grade H_2SO_4 and NaOH were used for pH modification and demineralised water was used throughout the experiment.

2.2 Characterization of Samples Used

A representative sample was picked from the lot and pulverized for determination of element composition on an Agilent 8800 Triple Quad ICP-MS. Consecutively, identification and quantification of the mineral phases was carried out on Malvern Panalytical Empyrean XRD. These compositions met the sample purity and characteristic requirement for the study.

2.2 Flotation Study

Artificial composite mixture in the ratio of 1:1 pyrite to arsenopyrite totalling 5 g lots were used in the flotation test. Flotation was performed at pH 6.4 after 30 mins conditioning in air. Following conditioning, SIBX and DTP in varying ratios (80:20, 50:50, 20:80) were added to the pulp for 5 minutes followed by MIBC addition for 2 mins. Flotation was carried out for 10 mins using an air flowrate of 1.5 ltrs/min. The flowsheet for the flotation experiment is presented in Figure 1. The recovery of arsenopyrite and pyrite were calculated using the As and Fe content respectively as shown in Equations (1) and (2) respectively. Using the first order rate Equation (3), the rate constant for each collector blend was calculated.

$$\%Asp = ((\%As\ in\ Conc. \times mass\ of\ conc.)/ (Mass\ of\ As\ in\ feed)) \qquad (1)$$

$$\%Py = (((\%Fe\ in\ Conc. - \%Fe\ contribution\ from\ Asp.) \times mass\ of\ conc.)/(Mass\ of\ Fe\ in\ feed)) \qquad (2)$$

$$R = Rmax(1 - e^{\wedge}(-kt)) \qquad (3)$$

where R is the recovery at time t, R_{max} is the maximum recovery at infinite time and k is flotation rate constant. k was inferred from Equation (3) for the various collector blends.
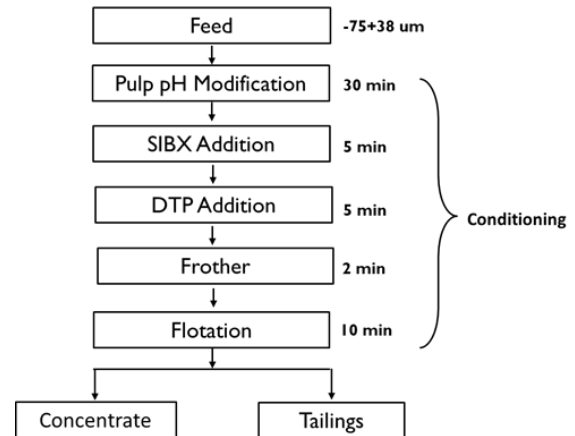

Figure 1 Flowsheet used for the flotation experiment

3. Results and Discussions

3.1 Mineralogical and Chemical Characterization of samples

The elemental composition of pyrite and arsenopyrite is shown in Table 1. The XRD patterns on the samples showed the predominance of pyrite and arsenopyrite in their representative model minerals as shown in Figure2.
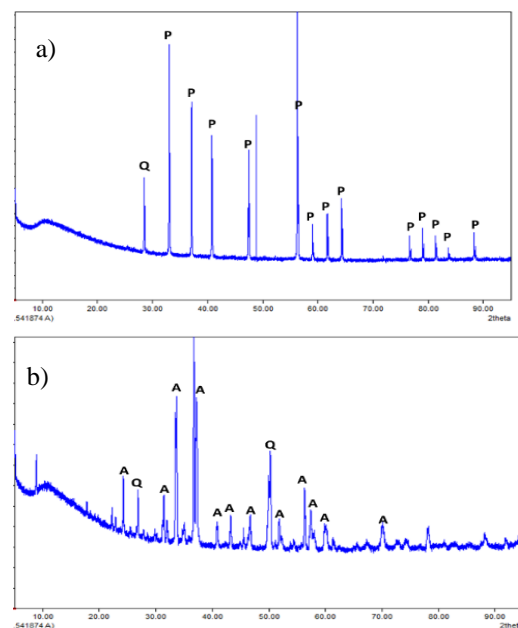

Figure 2 Diffraction patterns for a) pyrite and b) arsenopyrite minerals used in the study

Table 1 Elemental Composition of Pyrite and Arsenopyrite used for the Study

Element	Elemental Composition	
	Model Pyrite Sample	Model Arsenopyrite Sample
	%	%
Fe	44.23	32.90
S	48.57	16.30
As	0.03	39.80
Si	0.47	3.18
Cu	0.26	0.26
Pb	0.11	1.10
Al	<0.02	0.40
Mg	<0.01	0.40
Zn	0.13	0.72

Quantification of the mineral phases showed a high purity of pyrite (99.1 %) with quartz as the major gangue phase. On the other hand, arsenopyrite model mineral had a higher gangue constituent as shown in Table 2 but met the sample purity and characteristic requirement for this study.

Table 2 Quantitative Determination of Mineralogical Phases in Sample

Minerals	Mineralogy	
	Model Pyrite Sample	Model Arsenopyrite Sample
	wt.%	wt.%
Pyrite	99.1	-
Quartz	0.8	4.8
Arsenopyrite	-	86.0
Muscovite	-	3.94
Diaspore	-	3.0
Magnesium silicate	-	2.0
Galena	-	0.8

3.2 Bulk Flotation Recovery

The flotation recovery of the blends tested namely 80:20, 50:50 and 20:80 SIBX: DTP is presented in Figure 3. Comparison is made with flotation recovery using single collectors at the same concentration of 200 g/t. Bulk flotation recoveries were high for all ratios tested in comparison to singularly use of SIBX; a cumulative recovery of 64.5% was recorded. On the other hand, use of DTP only gave a relatively high recovery of 75.45%. Notwithstanding, the cost of using DTP only does not favour its singular use as a collector.
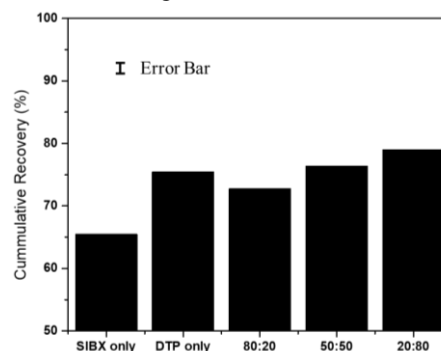

Figure 3 Bulk recovery of composite mixture

The recoveries from blending the two collectors supports the existence of a synergistic relation as recoveries were high. Although the mechanism for this observation is not yet understood, a high froth stability was evident and may have enhanced good mineral to froth contact. Additionally, a high surface distribution of the collector species on the mineral surface was proposed. Xanthate are easily oxidised to its dimer; dixanthogen which chemisorbs on the mineral surface (López Valdivieso *et al.*, 2005). Oxidation of dithiophosphate to its dimer (dithiophosphatogen) is however difficult and suggest a different form of collector interaction on the mineral surface (Lotter and Bradshaw 2010). The different collector species and adsorption mechanisms may have complemented each other and enhanced the flotation recovery in the process. Amongst the blends investigated, an increase in calculated flotation rate was observed with an increase in DTP content as shown in Table 3.

Table 3 Calculated flotation rate constant for blends of reagents tested

Flotation condition	Rate constant (min^{-1})
(SIBX)80:20(DTP)	0.90
(SIBX) 50:50 (DTP)	0.93
(SIBX)20:80 (DTP)	1.15
SIBX only	1.06
DTP only	1.37

Interestingly, comparing the rate constants for using the single collectors with the blends showed contrary behavior; high rate constants where observed for singular use of SIBX and DTP as shown in Table 3. In addition to a protracted flotation time, differences in the composition of concentrate was suggested and further investigated.

3.3 Pyrite-Arsenopyrite Selectivity

Analysis of the flotation concentrates for the effect of the synergist relationship on selectivity is shown in Figure 4. Limited by the masses of concentrated obtained between the time intervals, element composition for the first minute of flotation were determined as shown in Table 4.

Table 4 Measured Fe and As in concentrate obtained after 1 min

Flotation Condition	80:20	50:50	20:80	SIBX	DTP
Fe	39.08	39.33	38.75	40.64	39.79
As	11.90	11.79	14.22	6.13	12.78
Mass	2.08	2.15	2.63	2.30	2.33

The recovery of arsenopyrite is generally lower than that of pyrite due to its high susceptibility to oxidation and formation of hydrophilic surface species. In comparison with single collector use, the recovery of both pyrite and arsenopyrite increased with all the blend ratio tested. More so, an increase DTP content of the blend lead to an increase in the recovery of both pyrite and arsenopyrite but favoured the flotation of arsenopyrite over pyrite. This is desirable in the bulk flotation of auriferous sulphides where preferential concentration of gold in arsenopyrite exists (Asamoah *et al.*, 2019a; Asamoah *et al.*, 2019b; Chryssoulis and McMullen, 2016; Reich *et al.*, 2005). Moreover, the calculated high flotation rate constant for singular use of SIBX signified a more selective flotation of pyrite into the concentrate rather than an equal mass recovery of both minerals as shown in Figure 4.
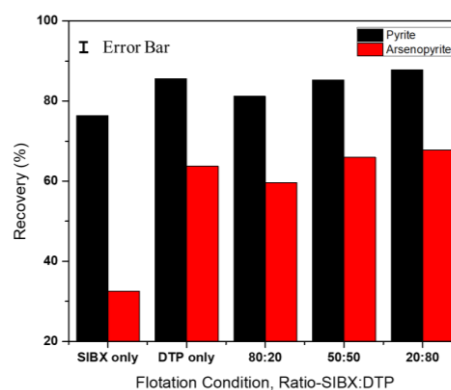

Figure 4 Effect of blends on selectivity of flotation

4 Conclusion

The recoveries obtained with blends of SIBX and DTP demonstrated a synergistic effect. The addition of DTP was seen to increase the flotation kinetics of admixture and increases with increase in DTP content. Flotation using DTP only gave the highest recovery, but the high cost of the reagent would limit it exclusive usage. Hence blending of these reagents

is recommended for high flotation recoveries. Moreover, a higher arsenopyrite recovery is greatly desired in the case of auriferous sulphides where preferentially concentration in arsenopyrite occurs.

Acknowledgements

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