

## RECENT DEVELOPMENTS IN FLOTATION REAGENTS TO IMPROVE BASE METAL RECOVERY

W.A. Grobler, S Sondashi and F.J. Chidley

Betachem (Pty) Ltd

### ABSTRACT

*Some of the challenges facing the flotation of base metal sulphides are the opening of new and varying ore bodies as well as maintaining essential skills in plants. Flotation reagent research focuses not only on improving flotation grade and recovery, but also on producing reagents robust enough to cope with changes. A group of recently developed co-collectors, activators, depressants and frothers are described together with a summary of results measured on base metal sulphide ores.*

### 1. INTRODUCTION

Some of the challenges facing the flotation of base metal sulphides are the opening of new and varying ore bodies as well as maintaining essential skills in plants. There is thus not only a need to develop new and exciting chemicals, but also a need to produce robust chemicals that are tolerant to these changes. In our quest to produce practical flotation reagents robust enough to cope with these changes while still optimizing grade and recovery, we have encountered a few interesting reagent combinations. This paper describes some of these reagents. Most of them are already in commercial use.

### 2. CO-COLLECTORS

Thiol collectors are widely used to float base metal sulphide minerals from milled ores. The most common thiol collector is Xanthate and to a lesser extent, di-thio-phosphate and di-thio-carbamate.

Xanthate adsorbs on to the surface of base metal sulphide particles via chemisorption, an ion exchange mechanism or an electrochemical mechanism depending on the sulphide mineral to be floated<sup>1</sup> or the nature of multiphase flotation system<sup>2</sup>. This multiphase flotation system is influenced by the oxidation of the sulphide surface, the oxidation of grinding media, the oxygen content in the pulp and the cathodic reduction

of oxygen, the electro-potential of the pulp, the hydrodynamic energy, water quality and the presence of reagents.

It is likely that this dynamic multiphase system will be different for each floatation plant or even during different periods in the same plant. It is thus not strange that most plants have developed unique collector dosing campaigns and often use a combination of collectors, or a co-collector, to produce a robust and tolerant collector system.

It has been reported that even under stable conditions the use of mixtures of thiol collectors result in improved flotation grade and recovery and increase the flotation kinetics. It is further reported that lower collector dosages are needed when mixtures are used<sup>3, 4</sup>

Almost all commercially available thiol collectors form charged ions and are water soluble. Klimpel<sup>4</sup> described a group of uncharged non water-soluble collectors and demonstrated their use. More recently, it is believed that, since these collectors are fundamentally different, their adsorption mechanism in the multiphase flotation system is also different and that they contribute to the adsorption mechanism of Xanthate.

A commercially available reagent consisting of a mixture of two uncharged, non water soluble collectors has been tested as a co-collector with Xanthate on a number of base metal sulphide ores. In all cases it has been found that by dosing a small amount (approximately 5 g/t) in the milling circuit, higher grades and recoveries of base metals were obtained. Some of these results are summarised in Table 1. As Klimpel<sup>4</sup> had observed, we also found that the flotation rate increased with the addition of this co-collector<sup>5</sup>.

*Table 1: Summary of flotation data measured with the addition of uncharged, non water-soluble co-collectors. The data shows the increase in recovery data from the baseline test.*

DEPOSIT TYPE	DATA SOURCE	RECOVERY CHANGE FROM THE BASELINE*		
		Ni	Cu	S
Nickel, copper deposit	Lab scale	+10.5%	+ 7.7%	
Nickel, copper deposit.	Plant test	+1.8%	+1.4%	+1.7%
Platinum rich base metal deposit.	Lab scale	+3.8%	+4.1%	+5.2%
Nickel, Copper deposit	Lab scale	+1%	+1%	+4%
Platinum rich base metal deposit.	Lab Scale	+0.7%	+0.7%	
Gold rich sulphide ore body.	Lab scale			+4%
Platinum rich base metal deposit.	Lab scale	+5%	+1.8%	
Nickel, copper deposit.	Plant test	+3%	+4%	
Copper, Cobalt deposit.	Plant test	+4%	+6%	
Copper (Sedimentary deposit)	Plant test		+5%	

## 2. ACTIVATORS

Copper sulphate is widely used in base metal sulphide flotation circuits to improve the process efficiency. As with Xanthates, the reactions involved are dependant on the ore type and the characteristics of the multiphase flotation system.

One mechanism described is the electrochemical reaction where the metal ion on the surface of the base metal sulphide particle is exchanged with a copper ion in solution, thus precipitating a copper rich sulphide on the surface of the particle. It is believed that the Xanthate adsorbs readily on the copper rich surface<sup>4</sup> and that a Xanthate-collector salt is formed by chemisorption. It is likely that this strong ionic bond acts as an anchor site for di-thiolates like di-xanthogen, which is the main chemical species promoting floatation<sup>4</sup>. It is thus believed that the copper ions do not form hydrophobic sites of their own, but are only intermediates in the formation of hydrophobicity. For copper sulphate to be successful as an activator, the multi phase conditions still have to be favourable for the formation of the Xanthate-metal salt on the surface of the particle.

A recent patent application<sup>4</sup> describes the use of a copper ion reacted with an organic compound to form an “organic copper activator”. The fundamental idea is to produce a copper based activator – collector combination externally, which does not need the formation of the Xanthate-metal salt formation as a necessary step in the activation process.

In all cases this “organic copper” was tested, it was found to be more effective than copper sulphate. Some results are given in Table 2.

*Table 2: Summary of flotation data measured with the addition of an organic copper activator. The data shows the increase in recovery data from the baseline test.*

DEPOSIT TYPE	DATA SOURCE	RECOVERY CHANGE FROM THE BASELINE*		
		Ni	Cu	S
Nickel, copper deposit.	Lab scale	+7.9%	+3.1%	+15.6%
Nickel, copper deposit.	Lab scale	+3.4%	+3.1%	

### 3. DEPRESSANTS

Polyglucosides<sup>8</sup> and sulfonates<sup>8</sup> have been described as depressants for silica and dolomites commonly found as gangue minerals in base metal flotation circuits. Again the mechanism of depression is complex and its effectiveness is influenced by the characteristics of the multiphase flotation system.

A mixed oxygenated polyglucoside and a sulphonated sodium condensate depressant was developed for the oxide flotation industry to depress silica and carbonates<sup>8</sup>. This depressant was tested on a number of base metal sulphide ore samples. With one exception, higher concentrate grade was measured. These results are summarised in Table 3.

Table 3: Summary of flotation data measured with the addition of a combination depressant. The data shows the increase in concentrate grade from the baseline test.

DEPOSIT TYPE	DATA SOURCE	CONCENTRATE GRADE CHANGE FROM BASELINE*		
		Copper	SiO <sub>2</sub> % & CaO & MgO & Al <sub>2</sub> O <sub>3</sub>	Insols
Copper deposit (Sedimentary)	Lab scale	+1.3%		-18.9%
Copper deposit (sedimentary)	Plant test	+4%		-3%
Copper deposit (sedimentary)	Plant test	+2%		-1%
Copper deposit (sedimentary)	Plant test	+9%		-10%
Nickel, Copper deposit	Lab scale		-8.5%	

### 4. FROTHERS

Frothers are no longer seen as reagents only producing froth. There is a better understanding of the interaction between collectors and frothers and the influence frothers have on the bubble size and hence bubble surface production rate and flotation kinetic rate.

The effect of frother type on the rate constant of various size fractions is well known<sup>8</sup> and there are well-defined optimal particle sizes and rates of flotation for individual frother species. To balance these variables in the multiphase system most plants currently use a mixed frother.

Recently, the retention time balance between the roughers and cleaners and the recirculation of plant water and cleaner tails has been recognised as important system characteristics in the design of frothers. Most frothers used on the Zambian Copperbelt today are combinations between water-soluble glycol ethers, non water-soluble glycol

ethers, linear alcohols and branched alcohols of various molecular weights. Matching the frother characteristic to the plant requirements has led to the decrease in frother consumption and total frother cost.

The non-water soluble co-collectors described in this paper are soluble in both alcohols and glycols. For some plants the logistical implication of adding 5 g/t of a co-collector that cannot be diluted with water are prohibitive. A frother has been developed where the co-collector forms part of the frother make-up and this eliminates the additional logistics of co-collector dosing.

## REFERENCES

1. Kuopanportti, H. Suorsa, T. & Pöllänen, E., Effects of oxygen on kinetics of conditioning in sulphide ore flotation, *Minerals Engineering*, Vol. 10, No. 11, pp 1193-1205, 1997
2. Chandler S., Fundamentals of Sulphide Mineral Flotation, *Advances in Flotation Technology*, Parekh B.K. & Miller, J.D., Society for Mining, Metallurgy and Exploration, Inc. 129-145 (19xx)
3. Bradshaw D. J. & O'Conner C.T., The flotation of pyrite using mixtures of Dithiocarbamates and other thiol collectors, *Minerals Engineering*, Vol. 7, No. 5/6, pp 681-690, 1994
4. Klimpel R.R., A Review of Sulphide Mineral Collector Practice, *Advances in Flotation Technology*, Parekh B.K. & Miller, J.D., Society for Mining, Metallurgy and Exploration, Inc. 115-127 (19xx) pp
5. Grobler W.A., Sondashi S., Examination of flotation reagents at STP for AGC, *unpublished*
6. Wills B.A., *Mineral Processing Technology, 4<sup>th</sup> Edition*, Chapter 12, Pergamon Press, Oxford (1988)
7. Chidley F.J., S.A. Patent (2003/9014), (2003).
8. Fuerstenau M.C., Adsorption of sulphhydryl collectors, *Principles of Flotation*, King R.P., South African Institute of Mining and Metallurgy, 91-108, (1982)
9. Zheng X., Smith R.W., Dolomite depressants in the flotation of apatite and cellophane from dolomite, *Minerals Engineering*, Vol. 10, No. 5, pp 537-545, 1997
10. Viljoen. R, Private communication

