



The effect of copper sulphate addition on the recovery of chromite in the flotation of UG2 ore

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Synopsis

Chromite and talc are two major gangue minerals in platinum bearing UG2 ore processed from the Bushveld Complex in South Africa. During flotation, talc is effectively depressed by the addition of depressants. Chromite, on the other hand, is considered to be hydrophilic, its recovery is believed to follow water recovery and therefore recovered by entrainment only. In certain cases it has been shown that chromite can be activated by the reagent suite and hence is made amenable to true flotation. The aim of the work was to investigate the effect of the addition of copper sulphate as an activator and the effect of the depressant type and dosage on the recovery of chromite. The results of these experiments showed that copper sulphate, at higher dosages, activated the chromite. Low dosages of copper sulphate resulted in no chromite activation. This was observed at low depressant dosages of both IMP4 (guar gum) and KU5 (carboxymethyl cellulose (CMC)). When the depressant dosages were increased, at higher copper sulphate dosages, it was observed that the activated chromite was depressed by IMP4, but that the activation was still significant with the use of KU5. The activation of the chromite is attributed to the form of the copper species present in the solution and on the mineral surfaces at pH = 9 enhancing collector adsorption and thereby increasing hydrophobicity. These species were not measured directly and it is recommended that this should be further investigated using surface mineral techniques.

Keywords: flotation; depressants; chromite; copper sulphate

Introduction

UG2 ore from the Bushveld Complex is mined in South Africa for its Platinum Group Metal (PGM) content. Two of the main gangue minerals found in the ore are talc and chromite. The PGMs are separated from the ore by flotation. In this process unwanted minerals are also recovered. Talc is naturally hydrophobic and its flotation is depressed by polymeric depressants. Chromite is considered to be hydrophilic and in general, its recovery follows water recovery as expected from the mechanism of recovery by entrainment. In some cases however, it has been reported that coarse chromite particles have reported to the concentrate suggesting that mechanisms other than entrainment can be responsible for the chromite recovery. It is believed that certain

reagent suites and in particular the addition of copper sulphate prior to collector addition could cause the chromite to be hydrophobic and hence amenable to true flotation (Wesseldijk *et al.* 1999).

The presence of chromite in the concentrate can result in inefficient smelter operations since it is a member of the spinel group that forms compounds that are stable to temperatures of up to 2000°C (McKenzie, 1996). As a result, there is a limit placed on the chromite grade obtained during flotation.

The reagents used in flotation are designed to maximize the recovery of the sulphide minerals that contain the PGMs and reduce the gangue content in the concentrate. In order to selectively recover the PGM minerals, thiol collectors are added with copper sulphate as an activator. At lower pH values, selective adsorption of Cu⁺⁺ or CuOH⁺ onto sulphide minerals is predominant which has been shown to be responsible for their activation (Laskowski *et al.* 1997). Thiol collectors are well known not to adsorb onto oxide minerals such as chromite. Due to the natural pH of PGM ores in the Bushveld Complex, the copper hydroxyl species present at pH 9 can cause unselective and inadvertent activation, which, with subsequent addition of collectors, can lead to true flotation as has been observed in other systems (Nagaraj and Brinen, 1995; Fuerstenau *et al.* 1970).

Polysaccharide depressants are added to minimize the recovery of talcaceous gangue minerals. The two main types of polysaccharide depressants used in the platinum industry are carboxymethyl cellulose (CMC) and guar gum (guar). These are high molecular weight polymers, with CMCs being straight chain polymers that tend to be charged whereas guar is branched polymers and are

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The effect of copper sulphate addition on the recovery of chromite

generally neutral in charge. As a result of this charged nature, CMC adsorption can induce particle dispersion in addition to having a depressant effect which can influence flotation performance (Shortridge *et al.* 1999; Dalvie *et al.* 2000).

The objective of this research was to determine the level of copper sulphate dosage that can activate the chromite and also to evaluate the effect of the depressant type and dosage on the recovery of chromite in the flotation of UG2 ore. The two depressants selected were for evaluation of the guar gum, IMP4 and the carboxymethyl-cellulose (CMC), KU5. Flotation performance was evaluated using the relationship of mass to water recovery as well as the chromite recovery.

Experimental details

The ore

The UG2 ore was obtained from the Bushveld Igneous complex in the North West province of South Africa. The UG2 ore consists mainly of chromite at a composition of roughly 26% by mass. The crushed ore was then homogeneously mixed and separated into 1 kg samples. Each sample was milled at 66 % solids to 40 % passing 75 microns immediately prior to flotation.

Reagents

A 1% solution of copper sulphate was prepared using $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$. The copper sulphate was always added prior to collector addition. As specified in the experiments performed, a dosage of either 30 g/ton or 90 g/ton was used. A copper sulphate dosage of 30 g/ton is the stoichiometric amount required to react with the thiol collectors. At 90 g/ton copper sulphate there would be excess copper ions in solution.

Senmin supplied the two thiol collectors used in the experiments. Sodium iso-butyl xanthate (SIBX) was made up as a 1% solution and 30 g/ton was used in each test. 30 μl SK5 (sodium dibutyl dithiophosphate (DTP)) was added as supplied by Senmin. The two collectors were added in the mass ratio of 1:1.

The two depressants were IMP4 (guar gum) supplied by Trohall and KU5 (CMC) supplied by G M Associates. These were added as specified and the dosages were varied between 100 g/ton and 200 g/ton to evaluate the effect of the depressant dosage on the recovery of chromite during flotation.

The DOW 200 frother was added at a concentration of 30 g/ton to create a suitably stable froth phase where the valuable minerals could be collected for further processing.

Batch flotation procedure

The flotation experiments were performed using a 3-litre Leeds batch cell in the Mineral Processing Laboratory at UCT. The batch cell was fitted with an impeller to maintain a good mineral distribution in the cell throughout the flotation time. The milled ore was transferred to the 3-litre Leeds cell to make up 33% solids. The impeller speed was kept at 1200 rpm. Copper sulphate was added into the cell and conditioned for 5 minutes. SIBX and SK5 was then added and conditioned for 2 minutes. Either IMP4 or KU5 was added and conditioned for 2 minutes. Finally DOW 200 was

added and conditioned for 1 minute. A constant air flowrate of 6 litres/minute was maintained throughout the flotation period. A feed sample of about 30 ml was taken using a syringe from the cell. The tails and concentrates were then dried and weighed.

The feed, concentrates and tail samples from the flotation tests were dried and digested by fusion with granular sodium peroxide and leaching with hydrogen peroxide and hydrochloric acid. The samples were then analysed for chrome content by atomic absorption.

Results and Discussion

The flotation tests were performed either in duplicates or triplicates. The standard deviations for the chromite recovery varied from 0.023 to 0.123 %. The standard conditions were set at an addition of 100 g/ton IMP4 with no copper sulphate addition. At these conditions, the chromite was expected to be recovered by entrainment only and follow the water recovery as shown by the linear relationship in Figure 1.

Figure 1 also shows that the copper sulphate dosage of 90 g/ton resulted in high levels of chromite recovery compared to those obtained at dosages of 0 and 30 g/ton. The dosage of 30 g/ton is the stoichiometric amount required to react with the collectors and hence no increased chromite recoveries were expected.

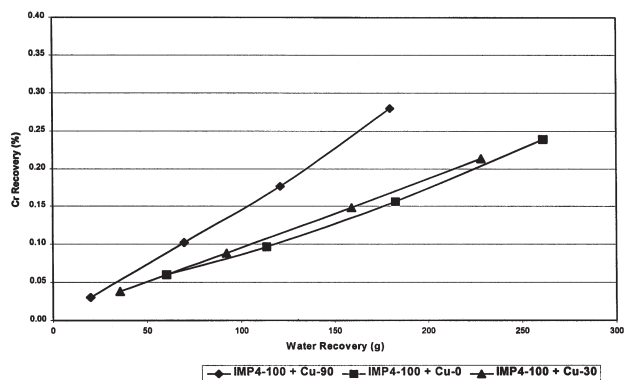


Figure 1—The effect of varying copper sulphate dosage on the chromite recovery of UG2 ore at a dosage of 100 g/ton of IMP4 at pH 9

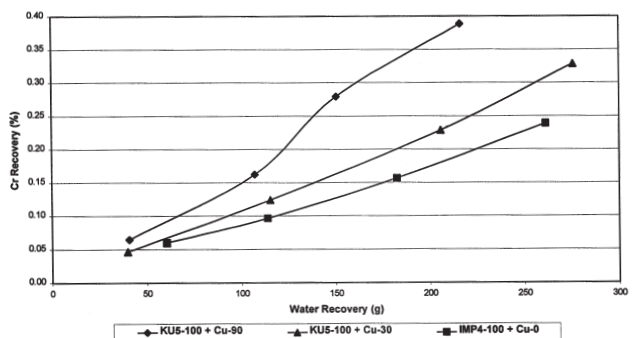


Figure 2—The effect of varying copper sulphate dosage on the chromite recovery of UG2 ore at a dosage of 100 g/ton of KU5 at pH 9

The effect of copper sulphate addition on the recovery of chromite

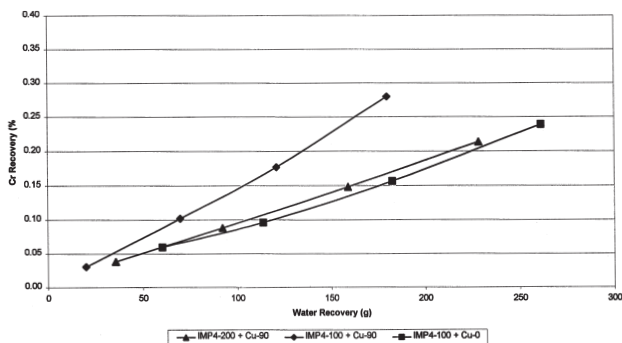


Figure 3—The effect on chromite recovery of UG2 ore by increasing the IMP4 dosage to 200 g/ton at pH 9 in combination with copper sulphate addition of 90 g/t

The equivalent tests were performed using KU5 (CMC). The same trend was observed showing that at 90 g/ton of copper sulphate, there was increased chromite recovery suggesting activation and that mechanisms other than entrainment are responsible for the chromite recovery. As with IMP4 at 30 g/ton of copper sulphate, no activation was observed.

Since high chromite recoveries were obtained at the dosage of 90 g/ton of copper sulphate and 100 g/ton of depressant, an increase of the depressant dosage was tested to evaluate whether the effect on chromite could be reversed. Figure 3 shows the effect of increasing IMP4 dosage to 200 g/ton. The results show that the recovery of chromite was reduced, which indicates that by increasing the IMP4 dosage it was possible to reduce chromite recoveries to those obtained at standard conditions.

Figure 4 illustrates that the increased KU5 dosage of 200 g/ton did not bring about a decrease in chromite recovery. The results show an initial increase in chromite recovery with reduced water recovery compared to that obtained with KU5 at a dosage of 100 g/ton. This indicates that the froth structure was affected and that there was a decrease in froth stability. This is consistent with the effect obtained with charged depressants such as CMCs observed by Robertson, 2003. He showed that the effect of increasing the addition of the charged inorganic dispersant, sodium hexameta-phosphate was to decrease froth stability and reduce water

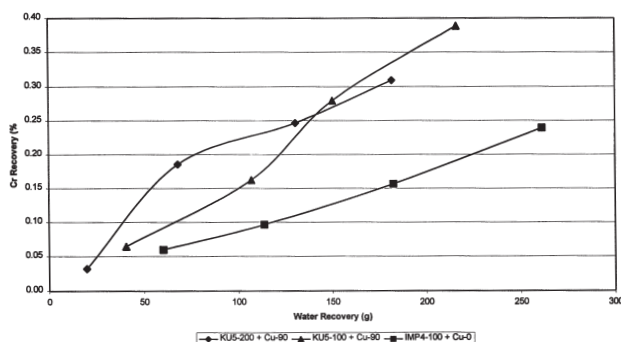


Figure 4—The effect on chromite recovery of UG2 ore by increasing the KU5 dosage to 200 g/ton for flotation tests with 90 g/ton copper sulphate at pH 9

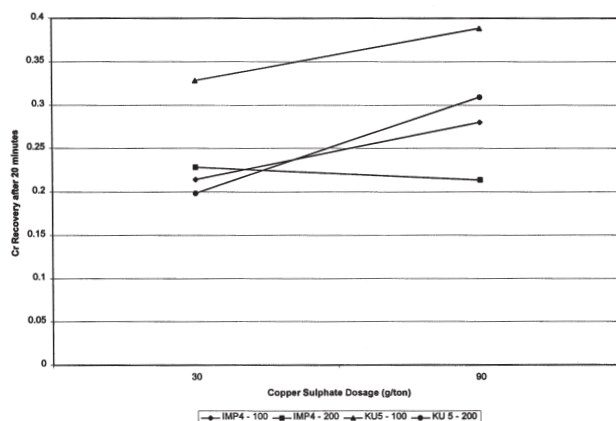


Figure 5—The effect of copper sulphate dosage on chromite recovery at various depressant dosages of IMP4 (guar) and KU5 (CMC)

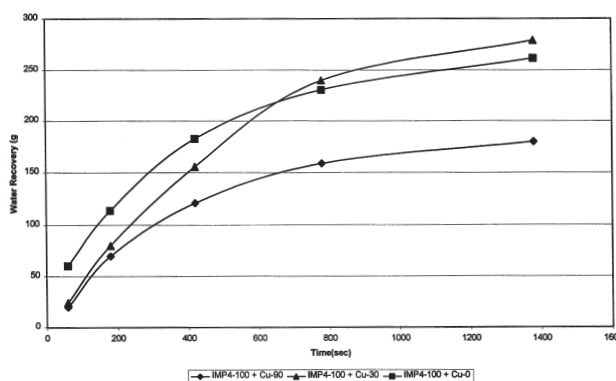


Figure 6—The effect of varying copper sulphate on water recovery obtained during flotation of UG2 ore at an IMP4 dosage of 100 g/ton

recovery. The differences in behaviour between CMCs and guar could also result from the lower adsorption of CMCs as observed by Steenberg and Harris, 1984.

Figure 5 shows that at 90 g/ton copper sulphate and 200 g/ton IMP4 lower chromite recoveries were obtained. The addition of KU5 at 100 g/ton gave the highest chromite recoveries with either 30 or 90 g/ton copper sulphate.

Figures 6 and 7 show the recovery of water with time and show that low water recoveries were obtained in systems where the copper sulphate dosage was 90 g/ton and the depressant dosage was 100 g/ton. This indicates reduced froth stability possibly resulting from increased mineral hydrophobicity or from the destabilizing effects of highly hydrophobic copper—xanthate species formed in excess copper conditions (Dippenaar, 1982a,b). As observed in Figures 1 and 2, these systems also showed higher chromite recoveries demonstrating that high copper sulphate dosages could result in increased chromite hydrophobicity resulting from activation.

Figure 8 shows the copper species present at pH 9, and it can be seen that $\text{Cu}(\text{OH})_2$ as well as lesser amounts of other copper hydroxide species are present as presented by Wesseldijk (1999). It is proposed that the mechanism of chromite activation is through the interaction of these species

The effect of copper sulphate addition on the recovery of chromite

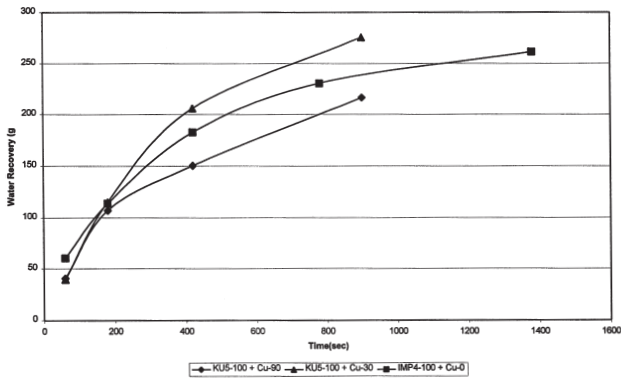


Figure 7—The effect of varying dosages of copper sulphate on water recovery obtained during the flotation of UG2 ore at a KU5 dosage of 100 g/ton

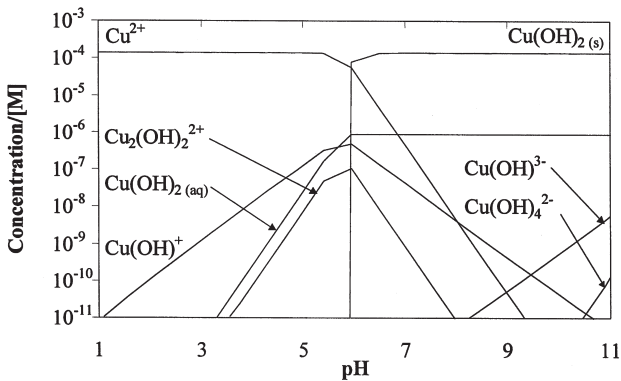


Figure 8—Logarithmic concentration diagram for $1 \cdot 10^{-4}$ M Cu^{++} (Fuerstenau et al. 1982)

with the mineral surface and subsequent increased adsorption of collector. It is also proposed that this can be reversed by the action of guar more effectively than that of CMCs but that should this be further evaluated using surface chemical techniques.

Conclusions and recommendations

The following conclusions can be made:

In the absence of copper sulphate addition, the lowest chromite recovery was achieved and as the relationship with water recovery was linear, it can be assumed to be recovered by entrainment. At low dosages of copper sulphate (i.e. 30 g/ton), chromite recovery was unaffected, showing that this resulted in no chromite activation.

The addition of 90 g/ton copper sulphate dosages at 100 g/ton depressant resulted in higher chromite recoveries than obtained in the standard tests, demonstrating inadvertent activation.

The addition of 200 g/ton IMP4 depressant in combination with 90 g/ton copper sulphate showed a reduction in the chromite recovery indicating a reversal of activation, whereas the addition of 200 g/ton KU5 did not reduce chromite recovery. This showed that IMP4 (guar) was more effective in reducing the chromite activation than KU5 (CMC).

No platinum assays were done in these tests and the work should be extended to evaluate the effect on PGM recovery and possibly identify an optimum copper sulphate dosage. Mineral surface studies should be done to confirm the form of copper species on the chromite surfaces.

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